# THE MINDFUL UNIVERSE (Jan. 8, 2003)

## 1. SCIENCE AND HUMAN VALUES.

This book is about what you are, and how you are connected to what you are not. It is about the impact of the revolutionary developments in physics during the twentieth century upon science's idea of you as a thinking and acting entity, and your linkage to the rest of nature.

These questions might appear to belong more to philosophy, metaphysics, or religion, rather than to physics, which is usually assumed to deal only with such tangible items as machines, rockets, transistors, and atomic bombs. But the radical change in our understanding of the physical world that occurred during the twentieth century has transformed connections that formerly had been matters of philosophical speculation into issues covered by basic physical theory. The aim of this book is to explain the new idea of the nature of human beings, and their causal role in the unfolding of reality, to readers with no prior understanding of the quantum character of the world.

Science has improved our lives in many ways. It has lightened the load of tedious tasks and expanded our physical powers, and thereby contributed to a great flowering of human creative energy. On the other hand, it has also given us the capacity to ravage the environment on an unprecedented scale and to obliterate our species altogether. Yet along with this fatal power it has provided a further offering which, though subtle in character and still hardly felt in the minds of men, may ultimately be its most valuable contribution to human civilization, and the key to human survival.

Science is not only the enterprise of harnessing nature to serve the practical needs of humankind. It is also part of man’s unending search for knowledge about the universe and his place within it. This quest is motivated not solely by idle curiosity. Each of us, when trying to establish values upon which to base conduct, is inevitably led to the question of one’s place in the greater whole. The linkage of this philosophical inquiry to the practical question of personal values is no mere intellectual abstraction. Martyrs in every age are vivid reminders of the fact that no influence upon human conduct, even the instinct for self preservation, is stronger than beliefs about one’s relationship to the power that shapes the universe. Such beliefs form the foundation of a person’s self image, and hence, ultimately, of that person's values.

It is often claimed that science stands mute on questions of values: that science can help us to achieve what we value once our priorities are fixed, but can play no role in fixing these weightings. That claim is certainly incorrect: science plays a key role in these matters. For what we value depends on what we believe, and what we believe is increasingly determined by science.

A striking example of this influence is the impact of science upon the system of values promulgated by the church during the Middle Ages. That structure rested on a credo about the nature of the universe, its creator, and man’s connection to that creator. Science, by casting doubt upon that belief, undermined the system of values erected upon it. Moreover, it put forth a credo of its own. In that “scientific” vision we human beings were converted from sparks of divine creative power, endowed with free will, to automatons---to cogs in a giant machine that grinds inexorably along a preordained path in the grip of a blind mechanical process.

Gone from this “scientific” picture of our species is any rational basis for the notion of a person’s responsibility for his own actions. Each of us is asserted to be a mechanical extension of what existed prior to his birth. Over that earlier situation one has no control. Hence for what emerges, preordained, from that prior state one can bear no responsibility.

Given this conception of man the collapse of moral philosophy is inevitable. For this notion of the human being provides no rational basis for any value but self interest: behavior promoting the welfare of others, including future generations, becomes rational only to the extent that such behavior serves one's own interests. Hence science becomes doubly culpable: it not only undermines the foundations of earlier value systems, but also strips man of any vision of himself and his place in the universe that could be the rational basis for any elevated set of values.

This mechanical view of nature and of man's place within it dominated science at the end of the nineteenth century. According to that notion, the physical universe is composed of tiny bits of matter, and the unfolding of the observed world over the course of time is completely fixed by direct contact interactions between these localized microscopic elements. Human beings, insofar as they are parts of this physically describable reality, are simply conglomerations of these tiny components, whose motions are completely fixed by interactions at the microlevel.

During the twentieth-century this simple picture of nature was found to be profoundly wrong. It failed not just in its fine details, but at its fundamental core. A vastly different conceptual framework was erected by the atomic physicists Werner Heisenberg, Niels Bohr, Wolfgang Pauli and their colleagues. Those scientists were forced to a wholesale revision of the entire subject matter of physical theory by the strange character of the new mathematical rules, which were invariably validated by reliable empirical data.

The earlier "classical" physics had emerged from the study of the observed motions of the planets and large terrestrial objects. The entire physical universe was then conceived to be made out of miniaturized versions of these large visible objects. Rules were found that appeared to control the behavior of these tiny entities, and the objects composed of them. But these laws were completely independent of whether we were observing the physical universe or not: the laws took no special cognizance of any acts of observation performed by human beings, or of any knowledge acquired from such observations. However, the baffling features of the data acquired during the twentieth century caused the physicists who were studying these phenomena, and trying to ascertain the laws that governed them, to turn the whole scientific enterprise upside down.

Perhaps I should say that they turned *what had been upside down* rightside up. For the word “science” comes from the Latin *scire*, “to know,” and what the quantum physicists claimed, basically, is that the proper subject matter of science is not what may or may not be “out there,” unobserved and unknown to human beings. It is rather what we human beings can *know*. Thus they formulated their new theory, called quantum theory, around the *knowledge acquiring actions* of human beings, and the knowledge acquired from these actions, not around some imagined-to-exist world out there. The whole focus of the theory was thus shifted from one that basically ignored our knowledge to one that is essentially about our knowledge.

This shift did not amount merely to looking at the same old physical world from an egocentric point of view. Rather the whole landscape was transformed into something so strange and unfamiliar that it seemed to be understandable only in terms of how it worked for us.

This modified conception of science differs from the old one in many fascinating mathematical ways that continue to excite the interest of physicists. However, it is the revised understanding of the basic nature of human beings, and of their causal role in the unfolding of reality, that is, I believe, the most exciting thing about the new physics, and probably, in the final analysis, the most important contribution of science to the wellbeing of our species.

The new theory, quantum theory, accounts in a uniform manner for all the observed successes of the earlier physical theories, and also for the immense accumulation of new data for which the earlier methods fail abysmally. But it describes a world built not out of bits of matter, as matter was understood in the nineteenth century, but rather out of a fundamentally different kind of stuff. According to the revised notion, physical reality behaves more like *spatially encoded information that governs tendencies for experiential events to occur*, than like anything resembling material substance.

Moreover, according to this new understanding, the world is governed not by one single uniform process, but by *two* very different processes, only one of which is analogous *to* the process described by classical physics. The quantum counterpart of the older classical process is the part of the new theory of main interest to physicists, engineers, and other workers *not* concerned with the mental side of reality. But anyone interested in the role in nature of our conscious thoughts, ideas, and feelings needs to understand the other process, because, according to quantum theory, it specifies how our conscious thoughts affect our physical actions.

Nothing like this action of mind on the physical body exists in classical physics. Indeed, there is nothing in the principles of classical physics that requires, or even hints at, the existence of such things as thought, ideas, and feeling, and certainly no rules that dictate how the idea-like aspects of nature influence the physical aspects. Indeed, it was precisely the absence of any notion of experiential-type realities in classical physics, or of any job for them to do, or of any possibility for them to do anything not already done by the tiny mechanical elements, that has been the bane of philosophy for three hundred years. Now, however, that material conception of nature that was the cause of so much philosophical dispute, has been found to be fundamentally false. It has been replaced by a radically different framework of ideas that not only reproduces all the verified results of the prior theory, and also the huge wealth of new data, but moreover put thoughts, ideas, and feelings into the driver's seat. The new theory, unlike the old one, gives our conscious mental efforts an important role to play in the unfolding of reality. This causal action of our minds does not just redundantly over-determine things that are already fully determined by the interactions of tiny bits of matter. Rather it specifies necessary conditions that need to be fixed in order to tie the theory to our human experiences, but that are not specified by anything else in the theory.

The original formulation of quantum theory was created by physicists gathered around Niels Bohr, at his institute in Copenhagen, and is called "The Copenhagen Interpretation." It remains the official doctrine, and is what is used in actual practice. However, it is formulated simply as a *set of rules* to be used by physicists as they go about their jobs of collecting data and making predictions. It is *fundamentally* a set of practical rules for how we human beings can fit the *knowledge* that we obtain by acting upon Nature, and observing her responses to our actions, into a mathematical structure that allows us to compute valid predictions about what those responses are likely to be.

It is important to appreciate the huge difference between this new kind of "physical theory" and the classical physical theory that it supercedes. The older theory was about tiny bits of matter, and how their behaviors were governed by the effects of the neighboring bits. The new theory is about bits of information or knowledge that agents acquire by performing purposeful actions. It is about the freedom provided by the theory for human agents to choose *which* actions they will take, and *when* they will take them, and about the *knowledge* we derive from our experiencing of Nature’s response to such a purposeful action.

I shall begin my explanation of these profound developments in science by emphasizing, in the words of the founders themselves, the central role played in new theory by “our knowledge.”

## 2. REALITY AS KNOWLEDGE.

What are you made of? What is reality made of? What does intuition say about this? What does science say?

The deliverance of intuition on these matters is not unambiguous. Western science and philosophy begins with Thales of Miletus, who proclaimed "All is Water!". Other Greeks believed the primordial stuff to be "Air", or "Earth", or "Fire", and Empedocles settled on all four. On the other hand, Leucippus and Democritus thought everything was composed of tiny invisible, immutable atoms. Two millennia later, it looked like the two atomists had gotten it right: Isaac Newton built his seventeenth-century theory of the universe on the idea of enduring miniscule particles, and John Dalton's atomic hypothesis explained many facts of chemistry.

This notion that everything is composed of small bits of matter encounters, however, a serious difficulty. The earlier idea that "air" was a primary ingredient allowed soul or spirit to be construed as constructed out of one of the primitive substances. But it was hard to see how such a thing as a sensation of the color "red" or "green", or a feeling of "pain" or "joy" could be fully described in terms of a collection of tiny immutable bits of matter careening through space. Given even supreme knowledge and comprehension, how could the motions of billions of particles in a person's brain/body be understood to produce, or be the very same thing as, a conscious sensation, or the *feeling* associated with the grasping of an idea? One can understand all manner of *motions of objects*, and of their *changing shapes*, in terms of the motions of their constituent parts, but there is a rationally unbridgeable gap between the purely geometrical concepts of motions of immutable atomic particles in space and the psychological realities of conscious sensations, feelings, ideas, and efforts.

Isaac Newton built his theory upon the ideas of the French philosopher Rene Descartes, who resolved this dilemma concerning the psychological realities by conceiving nature to be built out of two sorts of substances: "matter", which was located in and occupied space, and the "mental stuff" that our ideas, thoughts, sensations, feelings, and efforts are made of. This peculiar sundering of nature worked well in science for more than two hundred years, but was abandoned by physicists during the twentieth century. Once it became clear that the old mechanical notions could not possibly account for the growing mountain of data concerning the properties of the atoms the focus shifted from the idea of a material world existing “out there”, independently of our observations of it, to what the experiments were actually telling us. This opened the door to a new approach that dealt directly with *our knowledge* about the systems being examined, rather than with the system itself. An incredibly beautiful and rationally coherent new kind of mathematical structure was eventually created or discovered. But this new mathematics described not a self-sufficient physical reality that exists independently of all minds, but rather a radically new kind of physical reality that represents or expresses, among other things, the evolving state of our knowledge, and also the effective tendencies, or propensities, for new knowings to occur.

The initial formulation of quantum theory was devised by a group of physicists working closely with the Danish physicist Niels Bohr, and is, as already mentioned, called the "Copenhagen interpretation". This approach is closely tied to actual experimental procedures, and is built around the activities of human experimenters who design and perform experiments with some purpose in mind, and who later record and interpret the results of their observations. Because this initial formulation of the theory continues to define the way the theory is used in actual practice it is the touchstone of all of the various later formulations that sought to eliminate the essentially anthropocentric character of the original version. But these later versions, which we shall describe in due course, need to preserve the basic linkage between the mathematical structure of the theory and human knowledge if they are to retain intact the empirical content of the theory. This is because the empirical content resides, in the end, only in what we come to know, not in what is perhaps true but unknown.

In the introduction to his book "Quantum theory and reality" the philosopher of science Mario Bunge (1967) said:

"The physicist of the latest generation is operationalist all right, but usually he does not know, and refuses to believe, that the original Copenhagen interpretation---which he thinks he supports---was squarely subjectivist, i.e., nonphysical."

Let there be no doubt about this point. The original form of quantum theory, which is the one still used in actual practice, is subjective, in the sense that it is forthrightly about relationships among conscious human experiences, and it expressly recommends to scientists that they resist the temptation to try to understand the underlying processes of nature that are responsible for the correlations between our experiences that the theory correctly describes. The following brief collection of quotations by the founders gives a conspectus of the Copenhagen philosophy:

Heisenberg (1958a): "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior."

Heisenberg (1958b): "...the act of registration of the result in the mind of the observer. The discontinuous change in the probability function…takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change of the probability function."

Heisenberg (1958b :) "When the old adage `Natura non facit saltus' (Nature makes no jumps) is used as a basis of a criticism of quantum theory, we can reply that certainly our knowledge can change suddenly, and that this fact justifies the use of the term `quantum jump'. "

Wigner (1961): "the laws of quantum mechanics cannot be formulated...without recourse to the concept of consciousness."

Bohr (1934): "In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of our experience."

Bohr (1963): "Strictly speaking, the mathematical formalism of quantum mechanics merely offers rules of calculation for the deduction of expectations about observations obtained under well-defined classical concepts."

Bohr (1958): "...the appropriate physical interpretation of the symbolic quantum mechanical formalism amounts only to prediction of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physics concepts."

The references to `"classical physics concepts" is explained in Bohr (1958): "...it is imperative to realize that in every account of physical experience one must describe both experimental conditions and observations by the same means of communication as the one used in classical physics."

Bohr (1958) "...we must recognize above all that, even when phenomena transcend the scope of classical physical theories, the account of the experimental arrangement and the recording of observations must be given in plain language supplemented by technical physical terminology."

Bohr is saying that scientists do in fact use, and must use, the concepts of classical physics in communicating to their colleagues the specifications on how the experiment is to be set up, and what will constitute a certain type of outcome. He in no way claims or admits that there is an actual reality out there that conforms to the precepts of classical physics.

In his book "The creation of quantum mechanics and the Bohr-Pauli dialogue" (Hendry, 1984) the historian John Hendry gives a detailed account of the fierce struggles by such eminent thinkers as Hilbert, Jordan, Weyl, von Neumann, Born, Einstein, Sommerfeld, Pauli, Heisenberg, Schroedinger, Dirac, Bohr and others, to come up with a rational way of comprehending the data from atomic experiments. Each man had his own bias and intuitions, but in spite of intense effort no rational comprehension was forthcoming. Finally, at the 1927 Solvay conference a group including Bohr, Heisenberg, Pauli, Dirac, and Born come into concordance on a solution that came to be called "The Copenhagen Interpretation", due to the central role of Bohr and those working with him at his institute in Denmark.

Hendry says: "Dirac, in discussion, insisted on the restriction of the theory's application to our knowledge of a system, and on its lack of ontological content." Hendry summarized the concordance by saying: "On this interpretation it was agreed that, as Dirac explained, the wave function represented our knowledge of the system, and the reduced wave packets our more precise knowledge after measurement."

These quotations make it clear that, in direct contrast to the ideas of classical physical theory, quantum theory is about "our knowledge." We, and in particular our mental aspects, have entered into the structure of basic physical theory.

This profound shift in physicists' conception of the basic nature of their endeavor, and of the meanings of their formulas, was not a frivolous move: it was a last resort. The very idea that in order to comprehend atomic phenomena one must abandon physical ontology, and construe the mathematical formulas to be directly about the knowledge of human observers, rather than about the external real events themselves, is so seemingly preposterous that no group of eminent and renowned scientists would ever embrace it except as an extreme last measure. Consequently, it would be frivolous of us simply to ignore a conclusion so hard won and profound, and of such apparent direct bearing on our effort to understand the connection of our knowings to our bodily actions.

Einstein never accepted the Copenhagen interpretation. He said: "What does not satisfy me, from the standpoint of principle, is its attitude toward what seems to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)." (Einstein, 1951, p.667: the parenthetical word and phrase are part of Einstein's statement.);

and “What I dislike in this kind of argumentation is the basic positivistic attitude, which from my view is untenable, and which seems to me to come to the same thing as Berkeley's principle, {\it esse est percipi}. (Einstein, 1951, p. 669). [Transl: To be is to be perceived]

Einstein struggled until the end of his life to get the observer’s knowledge back out of physics. But he did not succeed! Rather he admitted that: "It is my opinion that the contemporary quantum theory constitutes an optimum formulation of the [statistical] connections." (ibid. p. 87).

He also referred to: "the most successful physical theory of our period, viz., the statistical quantum theory which, about twenty-five years ago took on a logically consistent form. This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events." (ibid p. 81).

One can adopt the cavalier attitude that these profound difficulties with the classical conception of nature are just some temporary retrograde aberration in the forward march of science: one may imagine, as some do, that a strange confusion has confounded our best minds for seven decades, and that the weird conclusions of physicists can be ignored because they do not fit our classical-physics-based intuitions. Or one can try to claim that these problems concern only atoms and molecules, but not the big things built out of them. In this connection Einstein said: "But the `macroscopic' and `microscopic' are so inter-related that it appears impracticable to give up this program [of basing physics on the `real'] in the `microscopic' domain alone." (ibid, p.674).

The quotations displayed above make clear the fact that Copenhagen quantum theory brings human consciousness into the theory in an essential way. The questions before us are these: How is this done? And how does this radical change in basic physics affect science's conception of the human person?

The principal question here concerns the causal role of our minds in the determination of our actions: Are our physical actions completely controlled by mechanical processes that are fully specified by short-range interactions between tiny localized mechanical parts, or, on the other hand, are our actions influenced, irreducibly, by psychological realities? Are the activities of our brains completely determined by "bottom-up" processes---i.e., by contact interactions between tiny material elements—or can there be also an essential "top-down" contribution: an effect of conscious mental activity, per se, that influences brain action in a way that is not a consequence of microscopic bottom-up processes alone?

According to quantum theory the answer to this question is 'Yes'! The immediate follow-up question is then: How can something having the character of an experiential or conscious reality enter rationally into the mathematical structure that describes the physical state of the brain? How can quantum theory resolve *the core problem of philosophy*, which is the apparent logical disconnect between our concept of mind and our scientific understanding of the nature of the physical world?

The answer, in brief, is this: Quantum theory is constructed by replacing the "properties" of classical physics by "actions", and *in this world of actions* the psychological and physical aspects of reality are entities of the same kind, linked by dynamical laws! My aim here is to explain to non physicists, in a lucid but technically accurate manner, how the dynamical bonding of these disparate realities is achieved.

## 3. ACTIONS AND INFORMATION.

The Anti-Newtonian Revolution

From the time of Isaac Newton to the beginning of the twentieth century science relegated consciousness to the role of passive viewer: our thoughts, ideas, and feelings were treated as impotent bystanders to a march of events wholly controlled by contact interactions between tiny mechanical elements. Conscious experiences, insofar as they had any influences at all on what happens in the physical world, were thought to be completely determined at the microscopic level by the motions of miniscule entities. Hence the experiential *felt realities* that make up our streams of consciousness were regarded as either irrelevant to physics or redundant, and were denied fundamental status in the basic theory of physics.

The founders of quantum mechanics made the revolutionary move of bringing conscious human experiences into basic physical theory in a fundamental way. In the words of Niels Bohr the key innovation was to recognize that "in the drama of existence we ourselves are both actors and spectators." [Bohr, Essays 1958/1962 on Atomic Physics and Human Knowledge]. After two hundred years of neglect, our thoughts were suddenly thrust into the limelight. This was an astonishing reversal of precedent because the enormous successes of the prior physics were due in large measure to the policy of excluding all mention of idea-like qualities from the formulation of the physical laws.

What sort of crisis could have forced the creators of quantum theory to make this radical innovation of injecting mind into the scientific description of physical reality? The answer to this question begins with a discovery that occurred at the beginning of the twentieth century. In the year 1900 Max Planck discovered and measured the "quantum of action." Its measured value is called "Planck's Constant." This constant specifies one of three basic quantities that are built into the fundamental fabric of the physical universe. The other two are the gravitational constant, which fixes the strength of the force that pulls every bit of matter in the universe toward every other bit, and the speed of light, which controls the response of every particle to this force, and to every other force. The integration into physics of each of these three basic quantities generated a monumental shift in our conception of nature.

Isaac Newton discovered the gravitational constant, which linked our understandings of celestial and terrestrial dynamics. It connected the motions of the planets and their moons to the trajectories of cannon balls here on earth, and to the rising and falling of the tides. Insofar as his laws are complete the *entire physical universe* is governed by mathematical equations that link every bit of matter to every other bit, and moreover fix the complete course of history for all times from physical conditions prevailing in the primordial past.

Einstein recognized that the "speed of light" is not just the rate of propagation of some special kind of wave-like disturbance, namely "light". It is rather a fundamental number that enters into the equations of motion of every kind of material substance, and, among other things, prevents any piece of matter from traveling faster than this universal limiting value. Like Newton's gravitational constant it is a number that enters ubiquitously into the basic structure of Nature. But important as the effects of these two quantities are, they are, in terms of profundity, like child's play compared to the consequences of Planck's discovery.

Planck's "quantum of action" revealed itself first in the study of light, or, more generally, of electromagnetic radiation. The radiant energy emerging from a tiny hole in a heated hollow container can be decomposed into its various frequency components. Classical nineteenth century physics gave a clean prediction about how that energy should be distributed among the frequencies, but the empirical facts did not fit that theory. Eventually, Planck discovered that the empirically correct formula could be obtained by assuming that the energy was concentrated in finite packets, with the amount of energy in each such unit being directly proportional to the frequency of the radiation that was carrying it. The ratio of energy to frequency is called "Planck's constant". Its value is extremely small on the scale of normal human activity, but becomes significant when we come to the behavior of the atomic particles and fields out of which our bodies, brains, and all large physical objects are made.

Planck's discovery shattered the classical laws that had been the foundation of the scientific world view. During the years that followed many experiments were performed on atomic particles and it was repeatedly found that the classical laws did not work: they gave well defined predictions that turned out to be flat out wrong when confronted with the experimental evidence. The fundamental laws of physics that every physics student had been taught, and upon much of the industrial and technological world was based, were not correct. But more importantly and surprisingly, they failed a way that no mere tinkering could ever fix. Something was fundamentally amiss. No one could say how these laws, which were so important, and that had seemed so perfect, could be fixed. No one could foresee whether a new theory could be constructed that would explain these strange and unexpected results, and restore rational order to the cosmos. But one thing was clear to those working feverishly on the problem: Planck's constant was somehow at the center of it all.

## The World of Actions

Werner Heisenberg was, from a technical point of view, the principal founder of quantum theory. He discovered in 1925 the completely amazing and wholly unprecedented solution to the puzzle: the quantities that classical physical theory was based upon, and which were thought to be numbers, *are not numbers at all* ! They are *actions*! Ordinary numbers, such as 2 and 3, have the property that the product of any two of them does not depend on the order of the factors: 2 times 3 is the same as 3 times 2. But Heisenberg discovered that one could get the correct answers out of the old classical laws if one decreed that certain of the numbers that are used to describe the properties of a physical system in classical physics are not ordinary numbers, but are rather actions having the property that the order in which they act matters!

This "solution" may sound absurd or insane. But mathematicians had already discovered that logically consistent generalizations of ordinary mathematics exist in which numbers are replaced by “actions” having the property that the order in which one lets them act matters. The ordinary numbers that we use for everyday things like buying a loaf of bread or paying taxes are just a very special case from among a broad set of rationally coherent mathematical possibilities. In this simplest case, A times B happens to be the same as B times A. But here is no logical reason why Nature should not exploit one of the more general cases, and there is no compelling reason why our physical theories must be based exclusively on ordinary numbers rather than on actions. Heisenberg’s theory, Quantum Theory, exploits the more general logical possibility.

Now all this may sound like a lot of mathematical tomfoolery, but the important point is that it leads to a revision of the scientific conception of nature of reality, and of human beings, that is so profound that it can impact upon the lives of ordinary people.

An example of the change introduced by Heisenberg may be helpful.

In classical physics the center-point of each physical object has, at each instant of time, a well defined location, which can be specified by giving its three coordinates *(x, y, z)* relative to some coordinate system. For example, the location of a spider dangling in a room can be specified by letting *z* be its distance from the floor, and letting *x* and y be its distances from two intersecting walls. Similarly, the *velocity* of that dangling spider, as she drops to the floor, blown by a gust of wind, can be specified by giving *the rates of change* of these three coordinates (x, y, z). If each of these three rates of change, which together specify the velocity, are multiplied by the weight (=mass) of the spider, then one gets three numbers, say (p, q, r), that define the "momentum" of the spider. So in classical physics you might use the set of three numbers denoted by (x,y,z) to represent the position of the center point of an object, and the set of three numbers called (p,q,r) to represent the momentum of that object. These are just ordinary numbers that obey the commutative property of multiplication that we all, hopefully, learned in 3$^{rd}$ or 4$^{th}$ grade: x*p equals p*x, where * means multiply.

Heisenberg's analysis showed that in order to make the formulas of classical physics describe quantum phenomena, x*p must be different from p*x. Moreover, he found that the difference between these two products must be Planck's constant. [Actually, the difference is Planck's constant multiplied by the imaginary unit *i,* which is a number such that *i* times *i* is minus one. --- Hey, no one said quantum mechanics was going to be easy.] Thus quantum theory was born by recognizing, or declaring, that the symbols used in classical physical theory to represent ordinary numbers actually represent *actions* such that their ordering in a sequence of actions is important. The procedure of creating the mathematical structure of quantum mechanics from classical physics by replacing numbers by corresponding actions is called "quantization."

This idea of replacing the numbers that specify where a particle is, and how fast it is moving, by mathematical quantities that violate the simple laws of arithmetic may strike you---if this is the first you've heard about it---as a giant step in the wrong direction. You might mutter that scientists should try to make things simpler, rather than abandoning one of the things we really know for sure, namely that the order in which one multiplies factors does not matter. But against that intuition you should bear in mind that this change works beautifully in practice: all of the tested predictions of Quantum Theory are borne out, and these include predictions that are correct to the incredible accuracy of one part in a hundred million. Thus it would appear that there must something very very right about quantum theory.

What is important about all this, in the larger context of human life, is that this replacement of numbers by actions disrupts old laws of physics in just such a way as to bring your conscious thoughts into physics as features of causal agents with “free choices”: it introduces mental *choices* that can influence your behavior, yet are controlled by no known law. This revision of the physics severs in one stroke the logical chain that had perplexed and hobbled philosophy for three centuries. It does this by replacing the idea that the physical world is a collection of tiny material particles and local fields by the idea that the realities of prime importance in a scientific account of nature are *the actions of agents who gather knowledge or information, and the knowledge or information that they gather.* The physical world, as represented in the theory, brings the knowledge-acquiring actions of agents, and the knowledge garnered by those actions, into the theory in fundamental and non eliminable way.

## Purposeful Actions and Experienced Feedbacks

But how is this huge turnabout achieved?

What sorts of actions are involved here?

Quantum theory is built upon the idea of purposeful actions by agents. Each such action is expected or intended to produce an experiential response or feedback. For example, a scientist might act to place a Geiger Counter near a radioactive source, and expect to see the counter either “fire” during a certain time interval or not “fire” during that interval. The experienced response, “Yes” or “No”, to the question “Does the counter fire during the specified interval?” specifies one bit of information. Quantum theory is built around such knowledge-acquiring actions of agents, and the knowledge that these agents thereby acquire.

Probing actions of this kind are performed not only by scientists. Every healthy and alert infant is engaged in making willful efforts that produce experiential feedbacks, and he soon begins to form expectations about what sorts of feedbacks are likely to follow from some particular kind of effort. Thus both empirical science and normal human life are based on paired realities of this action-response kind, and our physical and psychological theories are both basically attempts to understand these linked realities within a rational conceptual framework.

As another example, consider a single physical object, such as the dangling spider mentioned above, and the set of three numbers (x.y,z) that according to the ideas of classical physics specify where the (center of the) object is located. According to quantum theory, no one can never know *exactly* what the numerical values associated with these three symbols x, y, and z really are: no one can ever find out *exactly* where this center point lies. Correspondingly, quantum theory deems superfluous the notion that each object or particle has a well defined location, and uses the symbols that in classical physics represented these numbers to represent three other things, namely three corresponding *actions*, x, y, and z.

Although no one can know *exactly* where the spider is located, a human agent can, by a willful effort, initiate a purposeful action that normally will produce an experiential feedback that will provide *some information* pertaining to the location the spider. For example, one may, by an appropriate willful act, direct one's visual attention to the task of determining whether the spider *appears to move* during a certain time interval or rather remains stationary. Or one might endeavor to learn whether the spider appears to stay in her web during that interval or not. One bit of information will be supplied by the experienced answer to either one of these yes-or-no queries.

Doing experimental physics depends on someone's being able to distinguish experiences that meet specified criteria from those that do not. Someone must be able to say whether the Geiger Counter fired or not, or at least be able to say something about what is going on in the physical world. Science, as we know it, would be difficult to pursue if scientists could make no judgments based on their probing actions, and the resulting experiences, about what was happening in the physical world. Quantum theory thus descends from the airy plane of high-level abstractions, such as the notion of unseen and unseeable material particles, to the level of more nitty-gritty realities: purposeful actions and experienced feedbacks.

The basic action of an experimental physicist is to set up an experiment and observe the feedback to see whether it conforms or not to some well posed criterion. An analogous everyday action might be to make the mental effort to raise only one's third finger, or to sing a beautiful high C, and then check the feedback to see whether the intention of this purposeful action is realized.

These examples hint at how the quantum framework designed to cover laboratory procedures might be expanded to cover the full range of human endeavors.

A purposeful action by a human agent is partly an intention, described in psychological terms, and partly a physical action, described in physical terms. The feedback also is partly psychological and partly physical. In quantum theory these diverse aspect are all represented by logically connected elements in the mathematical structure that emerged from Heisenberg's discovery.

Actions, as they are represented in this underlying mathematical structure, are usually called “operators.” They act or operate on other entities of the same kind, and the order in which these operators act can be important. Thus if A denotes one of these operators and B denotes one of these operators then the symbol AB represents the action or operation of performing first B and then A.

The stipulation that product symbols should be read from right to left is a convention: one could adopt the rule that product symbols should be read from right to left, and some mathematicians do adopt that convention. But physicists, for historical reasons, usually read these formulas from right to left.

As already indicated, a key role in the theory is played by purposeful actions that are intended to produce a feedback that either conforms or does not conform to a certain condition. I shall call these purposeful actions “queries.” They enjoy a simple mathematical property, which I now describe.

Receiving the response “Yes” to some query is represented by an operator P, which depends on that query. Receiving the answer “No” is represented by (I-P), where the operator “I” represents the identity operator, which produces no change at all. But one cannot receive both the answer “Yes” and also the answer “No” to the same query. This incompatibility is expressed by imposing upon these operators the condition $(I-P)P = P–PP = 0$, or $P=PP$. Operators P having this property are called “projection operators,” and they play a central role in connecting purposeful actions and their experienced feedbacks to the mathematical structure.

The basic building blocks of quantum theory are, then, a set of purposeful actions by agents, and for each such action an associated collection of possible “Yes” feedbacks, which are the possible responses that the agent can judge to conform to the criterion associated with that purposeful act. All other possible feedbacks are classified as “No,” For example, the agent is assumed to be able to make the judgement “Yes” the spider stayed in its web or “No” the spider did not stay in its web.

All known physical theories involve idealizations of one kind or another. In quantum theory the main idealization is not that every object is made up of miniature planet-like objects. It is rather that there are agents that perform purposeful acts each of which can result in a feedback may conform to a certain criterion associated with that act. One bit of information is introduced into the world in which that agent lives, according to whether the feedback conforms or does not conform to that criterion. Thus knowing whether the spider moved or not places the agent on one or the other of two alternative possible distinct branches of the course of world history.

John von Neumann, in his seminal book, *The Mathematical Foundations of Quantum Mechanics,* calls this basic action by the name "Process I," and I shall adopt that terminology.

Each Process I action acts upon a physical state and transforms it. This physical state is represented in Heisenberg's space of actions by an operator that I shall call S. The basic rule of quantum theory is then this:

If P is the operator that specifies the collection of "Yes" responses associated with a particular Process I action, and S specifies the physical system upon which this action acts, then this Process I action changes the state S to the new state S'=PSP + (I-P)S(I-P). The first term, PSP, is associated with the feedback "Yes", and the second term, (I-P)S(I-P), is associated with a failure of the "Yes" response to occur.

This formula specifies how the purposeful action of an agent, the feedback generated by that action, and the effect of this action on the physical system being acted upon are all tied together in single mathematical structure. The new form S' of the state can be used to compute probabilities of future possible responses to future possible freely chosen purposeful actions. Thus the theory can be tested in the crucible of practical application.

These brief remarks reveal the enormous difference between classical physics and quantum physics. In classical physics the elemental ingredients are tiny invisible bits of matter that are idealized miniaturized versions of the planets that we see in the heavens, and that move in ways unaffected by our scrutiny, whereas in quantum physics the elemental ingredients are purposeful probing actions by agents, the feedbacks arising from these actions, and the effects of our actions on the physical states that embody or carry this information.

Once the character of these differences is appreciated it becomes plausible that quantum theory may be able to provide the foundation of a scientific theory of the human person that is better able than classical physics to integrate the physical and psychological aspects of his nature. For quantum theory deals directly with, and gives mathematical representations of, important psycho-physical realities, and it ties these diverse aspects of nature together by well-defined mathematical rules, whereas classical physics does not.

## Probabilities

The predictions of quantum theory are generally statistical: only the *probabilities* that the agent will experience each of the alternative possible feedbacks are specified: Which of these alternative possible feedbacks will actually occur in response to a Process I action is usually not determined by quantum theory.

The relevant probability formulas are:

Probability of "Yes" is Tr PSP/Tr S

Probability of "No" is Tr (I-P)S(I-P)/Tr S

These formulas involve the symbol Tr, which stands for "trace."

The trace operation means that the operator is to act back around upon itself, so that, for example, Tr ABC = Tr CAB =Tr BCA. The trace of any of the allowed operators is an ordinary positive number or zero. It is the trace operation that allows ordinary *numbers* to be extracted from the mathematical structure built from operators.

Free Choices

Orthodox quantum theory is formulated in a realistic and practical way. It is structured around the activities of human agents, who are considered able to freely elect to probe nature in any one of many possible ways. Bohr emphasized the freedom of the experimenters in passages such as:

"The freedom of experimentation, presupposed in
classical physics, is of course retained and corresponds
to the free choice of experimental arrangement for which
the mathematical structure of the quantum mechanical
formalism offers the appropriate latitude."

This freedom is the freedom to choose which experiment will be performed, and when it will be performed. It is the freedom to pick the projection operator P, and to specify when the Process I associated with that projection operator P occurs.

This freedom of action stems from the fact that in the original Copenhagen formulation of quantum theory the human experimenter is considered to stand outside the system to which the quantum laws are applied. Those quantum laws are the only precise laws of nature recognized by that theory. Thus, according to the Copenhagen philosophy, there are no presently known laws that govern the choices made by the agent/experimenter/observer about how the observed system is to be probed. This choice is*, in this very specific sense*, a "free choice."

The Copenhagen formulation of quantum theory involves separating the dynamically unified physical world into two parts, the observed and observing systems, which are described in very different ways: the observed system is described in terms of the mathematical operators mentioned above, whereas the observing system is described essentially in terms of the experiences of the agent.

This procedure based on a bifurcation of the world works beautifully in practice. But this chopping of the unified physical world into two parts that are described in different ways is a source of great dissatisfaction among those scientists who seek a rationally and dynamically coherent understanding of what is actually going on.

Von Neumann evaded this unnatural splitting of the physical world by including the entire physical world---including the bodies and brain of the human agents---in the physical reality that is described in terms of the mathematical operators. In this formulation the brain of the agent becomes the main pertinent part of observed physical system, and the intentional act of the agent is represented by a Process I change in the physical state S of his brain. But von Neumann's inclusion of the entire physical world does not resolve the "free choice" issue of which of all the logically possible Process I actions the agent will choose---i.e., which of all the logically possible projection operators P will be used---or when an agent will perform the next Process I action. These choices remain undetermined within orthodox quantum theory.

I shall discuss in subsequent chapters the important effects of the Process I actions of mind on brain. But an essential point of this book has already been made. According to classical mechanics, everything that happens in the physical world is determined by a single *bottom up* local-deterministic physical process, and we ourselves are, consequently, mechanical automata. This does not mean that in classical physics high-level processes can have no effect on low-level processes. Certainly the actions of macroscopic entities such as wheels, pistons, and weather patterns have important causal consequences, and hence high-level events, entities, and processes can certainly causally influence the course of low-level events. But in classical physics those top-down processes are simply partial and approximate re-expressions of certain features of the basic bottom up process, which is itself dynamically complete. In orthodox quantum theory, on the other hand, the human agents are governed by *two* processes. One of them is the bottom up local deterministic process that arises by quantizing the classical laws. But this process, called Process II by von Neumann, does not by itself yield any predictions concerning relationships between human experiences. Another process, namely Process I, is needed to complete the theory. This Process I is a genuine top-down process in the sense that it produces causal effects of experientially felt intentions of the agent upon his own brain and body. And this process involves choices that are not controlled or determined by any known law or rule of nature. Thus quantum theory, unlike classical physics, can yield a genuine rationally understandable top-down effect of mind upon brain that is *not determined* by the bottom-up local-deterministic process.

## Cloudlike Forms

Although the idea of the exact location of (the center point of) a physical object or particle is not used in orthodox quantum theory, the mathematics does contain, for any spatial region R *of nonzero size*, a projection operator P(R) such that the "Yes" answer to the query associated with P(R) corresponds to finding the (center point of the) object or particle in that region R. Consequently, one can get an idea of the spatial character of the state S associated with (the center point of) this object by considering a set of non-overlapping cubic regions R(i) of very small size that cover all of space, and then computing the value V(i) of Tr P(R(i))S/Tr S for each of these small cubic regions R(i). The sum of these values V(i) will be one (unity). The value V(i) specifies the *probability of finding* the center point of the object or particle in region R(i) if an appropriate experiment is performed.

The quantum state S that characterizes (the center point of) a physical object defines in this way a cloudlike form that is, specifically, a probability distribution in space.

## Simple Harmonic Oscillators

One of the most important and illuminating examples of this cloudlike structure is the one corresponding to a pendulum, or more precisely, to what is called a "simple harmonic oscillator." Such a system is one in which there is a restoring force that tends to push the center of the object to a single "base point" of lowest energy, and in which the strength of this restoring force is directly proportional to the distance of the center point of the object from this base point.

According to classical physics any such system has a state of lowest energy. In this state the center point of the object lies motionless at the base point. In quantum theory this system again has a state of lowest energy, but it is not localized at the base point: it is a cloudlike spatial structure that is spread out over a region that extends to infinity. However, the probability distribution represented by this cloudlike form has the shape of a bell: it is largest at the base point, and falls off in a prescribed manner as the distance the center point from the base point increases.

If one were to squeeze this state of lowest energy into a more narrow space, and then let it loose, the cloudlike form would explode outward, but then settle into an oscillating motion. Thus the cloudlike spatial structure behaves rather like a swarm of bees, such that the more they are squeezed in space the faster they move, and the faster the squeezed cloud will explode outward when the squeezing constraint is released.

## The double-slit experiment

The important difference between the behavior of the quantum cloudlike form and the somewhat analogous classical probability distribution is exhibited by the famous *double-slit experiment*. If one shoots an electron, an ion, or any other quantum counterpart of a tiny classical object, at a narrow slit then if the object passes through the slit the associated cloudlike form will fan out over a wide angle. But if one opens two closely neighboring narrow slits, then what passes through the slits is described by a probability distribution that is not just the sum of the two separate fanlike structures that would be present if each slit were opened separately. Instead, at some points the probability value will be *twice the sum* of the values associated with the two individual slits, and in other places the probability value drops nearly to zero, even though both individual fanlike structures give a large probability value at that place. These features of the quantum cloudlike structure make that structure very different from a classical-physics probability distribution, for in the classical case the probabilities arising from the two slits simply add.

The point here that the probability structure pertains to an *individual ion, or other quantum entity,* and persists even when the objects come one at a time. According to classical physics the individual tiny object must pass through either one slit or the other, so the probability distribution should be just the sum of the contributions from the two separate slits. But it is not. Quantum theory deals consistently with this and other non-classical properties of these cloudlike probability structures.

## 4. NERVE TERMINALS AND THE NEED TO USE QUANTUM THEORY.

Some neuroscientists who study the relationship of consciousness to brain process want to believe that classical physics will be adequate for that task. That belief would have been reasonable during the nineteenth century, but now, in the twenty-first, it is rationally untenable.

To assess quantum effects in brains within orthodox (i.e., Copenhagen or von Neumann) quantum theory one must use the von Neumann formulation, because Copenhagen quantum theory is formulated in a way that leaves out the quantum dynamics of the human observer's body and brain. It also renounces the effort to find out what is really going on. But von Neumann quantum theory makes the brain of the agent the physical system S upon which the crucial Process I acts. This process specifies the interaction between a person's stream of consciousness and the activity in his brain. That interaction drops completely out when one passes to the classical approximation. Hence ignoring quantum effects in the study of the mind-brain connection means ignoring the quantum effects of the mind upon the brain, and hence ignoring all effects of the mind of the agent upon his brain.

This general reason why quantum effects cannot in principle be ignored leads to further question: How important are the quantum effects in brain dynamics?

That the quantum features are extremely important is made particularly evident by an examination of the dynamics of nerve terminals.

Nerve Terminals

Nerve terminals lie at the junctions between two nerves, and mediate the connection between them. The way they work is this. Each “firing” of a nerve sends an electrical signal along that fiber. When this signal reaches the nerve terminal it opens up tiny channels in the terminal membrane, through which calcium ions flow into the interior of the terminal. Within the terminal are “vesicles”, which are small sacks containing chemicals called neurotransmitters. The calcium ions migrate from their entry channels to special sites, where they trigger the release of the contents of a vesicle into a gap between the terminal and a neighboring nerve. The released chemicals influence the tendency of the neighboring nerve to fire. Thus the nerve terminals, as connecting links between nerves, are basic elements in brain dynamics.

The channels through which the calcium ions enter the nerve terminal are called “ion channels.” At their narrowest points they are not much larger than the calcium ions themselves. This extreme smallness of the opening in the ion channels has profound quantum mechanical import. The consequence is essentially the same as the consequence of the squeezing of the state of the simple harmonic operator, or of the narrowness of the slits in the double-slit experiments. The narrowness of the channel restricts the lateral spatial dimension. Consequently, the lateral velocity is forced by the *quantum uncertainty principle* to become large. This causes the cloud associated with the calcium ion to *fan out* over an increasing area as it moves away from the tiny channel to the target region where the ion will be absorbed as a whole on some small triggering site.

This spreading of the ion wave packet means that the ion may or may not be absorbed on the small triggering site. Accordingly, the vesicle may or may not release its contents. Consequently, the quantum state of the vesicle becomes a *quantum superposition* consisting of a state where the neurotransmitter is released and a state where the neurotransmitter is not released. This quantum splitting occurs at every one of the trillions of nerve terminals.

What is the effect of this *necessary* incursion of the cloud-like quantum character of the ions into the evolving state of the brain?

A principal function of the brain is to receive clues from the environment, form an appropriate plan of action, and direct the activities of the brain and body specified by the selected plan of action. The exact details of the plan will, for a classical model, obviously depend upon the exact values of many noisy and uncontrolled variables. In cases close to a bifurcation point the dynamical effects of noise might even tip the balance between two very different responses to the given clues: e.g., tip the balance between the 'fight' or 'flight' response to some shadowy form.

The effect of the independent superpositions of the "release" or "don't release" options, coupled with the uncertainty in the timing of the vesicle release at each of the trillions of nerve terminals will be to cause the quantum mechanical state of the brain to become a smeared out superposition of different macro-states representing different alternative possible plans of action. As long as the brain dynamics is controlled wholly by Process II---which is the quantum generalization of the Newtonian laws of motion of classical physics---all of the various alternative possible plans of action will exist in parallel, with no one plan of action singled out as the one that will actually occur. Some other process, beyond the local deterministic Process II, is required to pick out one particular real course of physical events from the smeared out mass of possibilities generated by all of the alternative possible combinations of vesicle releases at all of the trillions of nerve terminals. That other process is Process I, which brings in the action of the mind of the agent upon his brain.

This explanation of why quantum theory is relevant to brain dynamics has focused on individual calcium ions in nerve terminals. That argument pertains to the Process II component of brain dynamics. But the equally important Process I component of the brain dynamics, which brings the mind of the agent into the dynamics, must be analyzed in terms of a completely different set of variable, namely certain *quasi-stable macroscopic degrees of freedom*. These specify the brain structures that enjoy the stability or persistence, and the causal connections, needed to represent purposeful actions and expected feedbacks. These variables need to be described.

## 5. QUANTUM BRAINS AND MENTAL PROCESSES.

Until now I have focused on the state of (the center of) a single quantum object. However, the mathematical description extends in a natural---and highly tested---way to the quantum counterparts of classical systems of many objects or particles. A main difference is that the “spatial structure” of the state S of a system of N ions, electrons, protons, or other objects or particles is a cloudlike structure in a space of 3N dimensions, rather than just 3 dimensions. This increase from 3 dimensions to 3N dimensions arises in the following way.

Suppose, for each of the N particles that make up the large object, one specifies a corresponding region in the physical 3-dimensional space. That is, one specifies set of spatial regions R1, R2, R3,…,RN. The mathematical structure of the theory contains an associated projection operator P such that the “Yes” response represents the possibility that the first particle is found to be in the region R1, the second particle is found to in the region R2, the third particle is found to be in the region R3, and so on.  This means that for *any specified arrangement of the simultaneous locations of each of the particles of a large system*, such as a brain, or some large part of the brain, there is projection operator P such that the “Yes” response corresponds to finding each of the N particles in the system in a pre-specified region centered at the corresponding specified location. Each of these regions R1, R2, …, RN, could be quite small. Thus the projection operator P that enters into the specification of a Process I action can pick out a very detailed multi-particle sub-state PSP of the state S of the entire brain, or of some large part of the brain. In other words, the “Yes” response could correspond to finding some large part of the brain to be in a reasonably well defined multi-particle internal state.

Actually, these sharply defined spatial regions R1, R2, … , RN, are not suitable for specifying Process I: the corresponding states would immediately “explode”, as would a swarm of bees confined to a box if the box were suddenly removed. The appropriate states will be more like the lowest-energy state of the simple harmonic oscillator discussed above, which tends to endure for a long time, or like the states obtained from such lowest-energy states by spatial displacements and shifts in velocity. Such states tend to endure as oscillating states, rather than immediately exploding. That is, in order to get the needed stability properties the projection operators P corresponding to purposeful actions should be constructed out of *oscillating states of macroscopic subsystems of the brain*, rather than out of sharply defined spatial states of the individual particles.

These oscillating states are not oscillating states of the individual particles. They are states of new variables that combine the variables of many individual particles together in ways such that the states of the new variables behave like oscillators. The use of such oscillatory modes is a standard procedure in both classical physics and quantum theory. Oscillating modes of the electromagnetic field integrate the contributions of billions of particles, and are good candidates for the elements out of which the pertinent operators P are constructed.

As emphasized before, the *need to use quantum theory* in brain dynamics arises from the smearing out action of Process II at the level of the ionic, and electronic, and atomic components of the brain. Hence the analysis is carried out at the individual-particle level. However, the opposing integrative and selective action of Process I, which brings in the mental (i.e., psychologically described) aspect involves a completely different set of variables. Process I is specified projection by operators P that single out quasi-stable large-scale patterns of brain activity that are the brain correlates of particular mental actions or events. The connection between the mental events and their physical representations can be fixed by trial and error processing dating back at least to the beginning of life, both of the individual agent and of his primordial progenitors.

## 6. AGENTS, EVOLUTION, AND THE QUANTUM ZENO EFFECT.

Human beings play a singular role in Copenhagen quantum theory: within that scheme science is viewed as a human endeavor, performed by human beings for human beings. Still, most scientists believe that *something* was going on before Homo sapiens arrived on the scene, and many hold that the task of science will not be finished until we have a science-based idea of what that something was, and how our species emerged from it.

My intention here is to locate the place of human beings in a broader non-anthropocentric setting. I believe that this can be done by building upon the foundation laid by the creators of quantum theory, rather than by retreating to a mechanistic conception of man that ignores consciousness, or tries to replace it by something else, such as a classically described brain process. Indeed, the approach of scientists and philosophers who base their thinking on the classical conceptualization of human brains depends on a promissory note that can never be redeemed.

That promise, or completely unsupported hope, is that *someday* we shall be able to understand how a conscious experience---a feeling or knowing---can either ***be***, or *be a necessary consequence of*, a structure built exclusively out of the elements specified by classical mechanics. However, as already noted, the classical concepts and laws entail all kinds of microscopic and macroscopic geometric, behavioral, and functional properties, but nothing in those concepts and principles can *ensure* or *dictate* that some changing arrangements of numbers assigned to space-time points, which is basically all that classical physics can ever provide, will *necessarily* be accompanied by, say, a “painful feeling”.

Thus feelings can be only gratuitous---not rationally entailed---add-ons to any structure built solely from entities possessing only the properties specified by the classical-physics concepts. Such supernumeraries, being entailed neither rationally, dynamically, nor logically, can be stripped away without affecting the course of physical events prescribed by the theory. Hence they are devoid of survival value. Nor can it be argued that feelings *must* emerge from such systems because we ourselves are the living proof. For we ourselves are certainly not built out of elements that conform to the idealized unphysical concepts that are the basis of classical physics. We, insofar as contemporary science has correctly informed us, are built out a very different kind of stuff that is more like information and tendencies for experiences to occur, than like classical matter.

In short: in order to get something like consciousness out of a theory one must put something like consciousness in. Orthodox quantum theory already requires, in order to yield well defined predictions, the existence of Process I, which by its intrinsic nature is both a dynamically efficacious element of the theory and a link between the experiential and physical aspects of the theory. Thus quantum physics already provides, *as a central feature of the dynamics,* an essential ingredient that was formerly provided by *meta*physics, namely a link between the physical attributes of an agent, which are described in geometrical terms, and experiential aspects described in psychological terms?

So far I have restricted myself to the orthodox framework created by the founders of quantum theory, and developed by John von Neumann. The focus of those works was on *human* agents, and on the intentional actions that create scientific experiments. Now I shall apply the same formulas and ideas more generally.

How, within a general quantum framework, can an evolutionary scenario work?

According to this theory, the universe is formed by the combined actions of Processes I and II. I shall not speculate on how the primordial “Big Bang” conditions emerged, but following that event the universe could initially evolve for some time under the governance of Process II alone. All possible physical structures would be generated in parallel by this mechanically evolving cloud-like quantum state of the universe. Given the nature of the structures governed by the physical laws---which support, among other things, the possibility of the formation of organic molecules---the set of all possibilities will eventually include the formation of potential agents, which are basically systems that can endure as physical structures that can influence their own destinies by means of Process I actions.

The mechanical Process II is well understood in the regime pertaining to human bodies, and the basic dynamical equations pertaining to Process I events are fixed. But three critical questions remain:

(1) What determines the specific form of the projection operator P in an occurring Process I event?

(2) How is that event related to the “feeling” aspect of nature?

(3) What determines when that Process I event occurs?

The known laws of quantum theory do not fully answer these questions. But within a scientific context it is reasonable to assume that nothing definite happens without some sort of cause, and that, moreover, the cause of a Process I event associated with some agent involves the state S of that agent or his brain.

Process I influences the state S according to the rules spelled out above. Hence one can expect the state S to reciprocally influence Process I. Indeed, the empirical fact that thoughts depend on earlier thoughts buttresses the idea that causal connections act not only from mind to brain but also from brain to mind. Knowing the form of the Process I action of mind on brain should help us to understand the reciprocal action of brain upon Process I. For actions in nature are usually closely connected to their reciprocals.

Purposeful Process I actions already exhibit some influence of brain on mind: the intention tends to create a new state PSP that embodies that intention. But within the prior state S lurks the component PSP that embodies the intention that the Process I action will tend to actualize.

To get suitable reciprocity I assume that the state S of an active agent has a property that singles out an associated preferred projection operator P(S). All sorts of "maximal" properties could be imagined that would pick out a favored P(S). But within the context of a theory of evolution what is needed is a process for determining the favored operator P(S) that will tend to produce corresponding Process I actions that will tend to promote the survival of species.

The rule that determines the operator P(S) is presumably determined by natural selection: only those species of agents structured in such a way that their determination of the favored operator P(S) promotes their survival would be around today in large numbers.

There is the further question of just *when* the Process I action occurs.

To address this question I shall assume, following a suggestion of Benjamin Libet, and many other psychologists, that the actualization of a Process I action is triggered by a "consent" on the part of the agent, and that the rapidity with which consent is given can be increased by "mental effort": the Process I action specified by P(S) occurs if and only if "consent" is given, and "mental effort" can cause consents to be given with greater rapidity.

Each Process I action separates the prior physical reality into two independent branches, 'Yes' and 'No'. The theory assigns a statistical weight to each branch. The weights associated with the 'Yes' and 'No' branches are given by the formulas Tr PSP/Tr S and Tr (I-P)S(I-P)/Tr S, respectively. Subjectively, these statistical weights determine the "probabilities" that the agent will experience the 'Yes' feedback or will not experience that feedback. These probabilities determine also the propensity for an agent who is observing the agent to observe the latter's actions to accord with the possibility PSP or (I-P)S(I-P).

The simplest explanation of these statistical properties is that "Nature chooses" either the state PSP or the state (I-P)S(I-P) in accordance with a "propensity" or "objective tendency" specified by the above formulas. However, it should be mentioned that von Neumann himself did not explicitly specify that this objective choice of one branch or another actually occurs. All that the empirical evidence confirms is that our subjective experiences are "as if" this objective choice occurs, and von Neumann apparently did not wish to say more.

The suggestion that this "reduction" to either the "Yes" branch or the "No" is merely a subjective illusion has some metaphysical advantages in connection with the idea that there ought to be no actual faster-than-light transfer of information. But it raises questions as to the meaning of the relative probabilities of "Yes" and "No" if both possibilities actually occur. For ontological clarity I shall speak as if this reduction to one branch or the other really does occur, although empirical validation of this idea is presumably impossible, if all subjective experience is "as if" this were true.

## The Quantum Zeno Effect

An important feature of Process I is this: Suppose a Process I event that gives a "Yes" outcome PSP is followed by a sequence of Process I events that are specified by a sequence very similar projection operators P(i), with the index i running over a sequence of integers, and that the events in this sequence occur in rapid succession on the time scale of the evolution of the state PSP. Then the dynamical rules stated above entail, with high probability, that the sequence of outcomes will all be “Yes”: with high probability the nth state in the succession of chosen states will be of the form P(n)S(n)P(n). The slowly changing succession of P(i)’s means that some aspect of intentionality will be held approximately in place by the rapid succession of slowly changing purposeful acts.

If the rapidity of these events is sufficiently great then this “Quantum Zeno Effect” can prevail, and hold in place these properties specified by the projection operators P(i), even in the face of very strong disruptive Process II forces: rapid-fire Process I actions can override the mechanical forces that drive Process II, and keep a slowly varying intention in place in a situation in which the mechanical forces associated with Process II would strongly tend to drive the brain into a very different sort of state.

This potentially powerful effect of mental effort on brain activity is a rigorous mathematical consequence of the basic quantum laws described above.

The Quantum Zeno Effect was given this name by the physicists E.C.G. Sudarshan and R. Misra, because of its similarity to a paradox discussed by the fifth century B.C. Greek philosopher, Zeno the Eleatic. The quantum version has been extensively studied and often empirically confirmed in recent years in various different experimental contexts.

The “Quantum Zeno Effect” can hold a purposeful intention in place in the face of strong mechanical forces that would tend to disrupt it. This means that agents whose efforts can influence the rapidity of Process I actions would enjoy a survival advantage over competitors that lack such features, for they could sustain beneficial activities longer than their Process I deprived competitors. This gives the leverage needed for natural selection.

This conceptualization is causal, but the causal structure is non-local, firstly because the operators P(S) act instantaneously over sizeable regions, and secondly because a “mental effort” is a (truly existing) reality that *does something* non-local to a dynamical process in space-time, while not itself being a specified structure localized in space-time.

## 7. PSYCHO-PHYSICAL THEORY AND "WILL."

A person's experiential life is a stream of conscious experiences. The person's experienced 'self' is *part* of this stream of consciousness: it is not an extra thing that is outside or apart from the stream. In James's words "*thought is itself the thinker*, and psychology need not look beyond." The "self" is a slowly changing "fringe" part of the stream of consciousness. It provides a background for the central focus of attention.

The physical brain, evolving mechanically in accordance with the local deterministic Process II does most of the necessary work, without the intervention of Process I. It does its job of creating, on the basis of its interpretation of the clues provided by the senses, a suitable response. But, due to its quantum nature, the brain necessarily generates an amorphous mass of overlapping and conflicting templates for action. Process I acts to extract from this jumbled mass of possibilities a dynamically stable configuration in which all of the quasi-independent modular components of the brain act together in a maximal mutually supportive configuration of non-discordant harmony that tends to prolongs itself into the future and produce a subsequent feedback. This is the preferred "Yes" state PSP that specifies the form of the Process I event. But the quantum rules do not assert that this preferred part of the prior state S necessarily comes into being: they assert, instead, that if this process is activated---say by some sort of "consent"---then this "Yes" component PSP will come into being with probability Tr PSP/Tr S.

And the rate at which consents are given is assumed to be increasable by mental effort.

The phenomena of "will" is understood in terms of this effortful control of Process I, which can, by means of the Quantum Zeno Effect, override strong mechanical forces arising from Process II, and cause a large deviation of brain activity from what it would be if no mental effort were made, and the consents were therefore given out much more slowly.

Does this quantum-physics-based conception of the connection between mind and brain explain anything?

This theory was already in place when a colleague, Dr. Jeffrey Schwartz, brought to my attention some passages from ``Psychology: The Briefer Course'', written by William James. In the final section of the chapter on Attention James writes:

``I have spoken as if our attention were wholly determined by neural conditions. I believe that the array of things we can attend to is so determined. No object can catch our attention except by the neural machinery. But the amount of the attention which an object receives after it has caught our attention is another question. It often takes effort to keep mind upon it. We feel that we can make more or less of the effort as we choose. If this feeling be not deceptive, if our effort be a spiritual force, and an indeterminate one, then of course it contributes coequally with the cerebral conditions to the result. Though it introduce no new idea, it will deepen and prolong the stay in consciousness of innumerable ideas which else would fade more quickly away. The delay thus gained might not be more than a second in duration---but that second may be critical; for in the rising and falling considerations in the mind, where two associated systems of them are nearly in equilibrium it is often a matter of but a second more or less of attention at the outset, whether one system shall gain force to occupy the field and develop itself and exclude the other, or be excluded itself by the other. When developed it may make us act, and that act may seal our doom. When we come to the chapter on the Will we shall see that the whole drama of the voluntary life hinges on the attention, slightly more or slightly less, which rival motor ideas may receive. ...''

In the chapter on Will, in the section entitled ``Volitional effort is effort of attention'' James writes:

``Thus we find that we reach the heart of our inquiry into volition when we ask by what process is it that the thought of any given action comes to prevail stably in the mind."

and later

``The essential achievement of the will, in short, when it is most `voluntary,' is to attend to a difficult object and hold it fast before the mind. ... Effort of attention is thus the essential phenomenon of will."

Still later, James says:

``Consent to the idea's undivided presence, this is effort's sole achievement."...
``Everywhere, then, the function of effort is the same: to keep affirming and adopting the thought which, if left to itself, would slip away."

This description of the effect of mind on the course of mind-brain process is remarkably in line with what had been proposed independently from purely theoretical considerations of the quantum physics of this process. The connections specified by James are explained on the basis of the same dynamical principles that had been introduced by physicists to explain atomic phenomena. Thus the whole range of science, from atomic physics to mind-brain dynamics, is brought together in a single rationally coherent theory of an evolving cosmos that consists of a physical reality that is constituted not of matter but of tendencies for Process I events to occur.

Much experimental work on attention and effort has occurred since the time of William James. That work has been hampered by the apparent nonexistence of any physical theory that rationally explains how our conscious experiences could influence activities in our brains. The behaviorist approach, which dominated psychology during the first half of the twentieth century, and which essentially abolished in this field the use not only of introspective data but also of the very concept of consciousness, was surely motivated in part by the fact that consciousness was excluded from any role in brain dynamics by the physics of the preceding century

The admitted failure of the behaviorist programs led to the rehabilitation of ``attention'' during the early fifties, and many hundreds of experiments have been performed during the past fifty years for the purpose of investigating empirically those aspects of human behavior that we ordinarily link to our consciousness.

Harold Pashler's 1998 book ``The Psychology of Attention'' [32] describes a great deal of this empirical work, and also the intertwined theoretical efforts to understand the nature of an information-processing system that could account for the intricate details of the empirical data. Two key concepts are the notions ``Attention'' and of a processing ``Capacity''. The former is associated with an internally directed selection between different possible allocations of the available processing ``Capacity''. A third concept is "Effort", which is linked to incentives, and to reports by subjects of ``trying harder''.

Pashler organizes his discussion by separating perceptual processing from post-perceptual processing. The former covers processing that, first of all, identifies such basic physical properties of stimuli as location, color, loudness, and pitch, and, secondly, identifies stimuli in terms of categories of meaning. The post-perceptual process covers the tasks of producing motor actions and cognitive action beyond mere categorical identification. Pashler emphasizes [p. 33] that ``the empirical findings of attention studies specifically argue for a distinction between perceptual limitations and more central limitations involved in thought and the planning of action.'' The existence of these two different processes, with different characteristics, is a principal theme of Pashler's book [p. 33, 263, 293, 317, 404]

In the quantum theory of mind-brain being described here there are two separate processes. First, there is the unconscious mechanical brain process called Process II. As discussed at length in my earlier book, Mind, Matter, and Quantum Mechanics, this brain processing involves dynamical units that are represented by complex patterns of neural activity (or, more generally, of brain activity) that are ``facilitated'' (i.e., strengthened) by use, and are such that each unit tends to be activated as a whole by the activation of several of its parts. The activation of various of these complex patterns by cross referencing---i.e., by activation of several of its parts---coupled to feed-back loops that strengthen or weaken the activities of appropriate processing centers, appears to account for the essential features of the mechanical part of the dynamics in a way not greatly different from that of a classical model, except for the creation of a superposition of a host of parallel possibilities that according to the classical concepts could not exist simultaneously.

The second process, von Neumann's Process **I** must come into play in order to select what actually happens from the continuum of alternative possibilities generated by Process II.

Process I, which is connected to conscious awareness and what actually happens, has itself two modes. The first involves mere passive consent, and a single isolated event: the second involves mental effort, and a sequence of events that bring importantly into play the Quantum Zeno Effect. The “perceptual” aspect of brain process discussed by Pashler can be associated with Process II, and the passive or merely consensual aspect of Process I, whereas the higher-level processing that Pashler identifies can be associated with the active mode of Process I, which involves a sequence of effortfully sustained Process I purposeful actions.

[I am assuming here that even a nearly automatic attending, such as attending to a nearby clap of thunder, or to a sudden unexpected pain, involves some subtle element of “consent.” But the theory could be tweaked on that point.]

The quantum conception of brain dynamics seems to accommodate all of the perceptual aspects of the data described by Pashler as automatic or near automatic processing. But it is the high-level processing, which is linked to active mental effort, that is of prime interest here. The data pertaining to this second kind of process is the focus of part II of Pashler's book.

Active Process I intervention has, according to the quantum-physics-based theory described here, a distinctive form. It consists of a sequence of purposeful actions, constructed by the conditioned brain, the rapidity of which can be increased with effort. Effort-induced speed-up of the rate of occurrence of these events can, by means of the quantum Zeno effect, keep attention focused on an intention. Between 100 and 300 msec of consent seem to be needed to fix a plan of action.

Effort can, by increasing the number of purposeful events per second, increase the input of mental intention into brain activity.

There are three kinds of experiences: consent, effort, and confirmation. Consent is consent to perform a particular purposeful action, which may be only to register some available input, effort is effort to try harder to do that action, and confirmation is confirmation of success in doing that action. A purposeful action may be a “shotgun” action consisting of a collection of mutually compatible similar actions only one of which will be confirmed. [[The corresponding set of projection operator P(i) must satisfy P(i)P(j)=0 for i different from j.]]

The purposeful action is the Process I action, and the confirmation confirms the actualization of the “Yes” possibility.

These connections conform to the core ideas of Copenhagen quantum theory: The purposeful action, represented by Process I, determines how the agent acts on the observed system, and the feedback reveals nature’s response to this action.

Examination of Pashler's book shows that this quantum-physics-based theory accommodates naturally all of the complex structural features of the empirical data that he describes. He emphasizes [p. 33] a specific finding: strong empirical evidence for what he calls a central processing bottleneck associated with the attentive selection of a motor action. This kind of bottleneck is what the quantum-physics-based theory predicts: the bottleneck is precisely the single linear sequence of Process I actions that quantum theory is built upon.

Pashler [p. 279] describes four empirical signatures for this kind of bottleneck, and describes the experimental confirmation of each of them. Much of part II of Pashler's book is a massing of evidence that supports the existence of a central process of this general kind.

This bottleneck is not automatic within classical physics. A classical model could easily produce simultaneously two responses in different modalities, say vocal and manual, to two different stimuli arriving via two different modalities, say auditory and tactile. The two processes could proceed via dynamically independent routes. Pashler [p. 308] notes that the bottleneck is undiminished in split-brain patients performing two tasks that, at the level of input and output, seem to be confined to different hemispheres.

The queuing effect for the mind-controlled motor responses does not exclude interference between brain processes that are similar to each other, and hence that use common brain mechanisms. Pashler [p. 297] notes this distinction, and says ``the principles governing queuing seem indifferent to neural overlap of any sort studied so far.''

In the quantum model the queuing is associated with the sequence of actions generated by active effort. I shall assume that at a given level of effort only a certain number of actions per second is allowed. But the individual actions are specified by non-local operators P. and each one can involve simultaneously several different macroscopic brain processes that may or may not involve neural overlap. So the model is quite in line with Pashler's observation.

An interesting experiment mentioned by Pashler involves the simultaneous tasks of doing an IQ test and giving a foot response to rapidly presented sequences of tones of either 2000 or 250 Hz. The subject's mental age, as measured by the IQ test, was reduced from adult to 8 years. [p. 299] This result supports the prediction of quantum theory that the bottleneck pertains both to `intelligent' behavior, which requires effortful conscious processing, and to effortful selection of motor response. Effort can be divided, but at a maximal level there is a net total rate of effortful Process I actions.

Another interesting experiment showed that, when performing at maximum speed, with fixed accuracy, subjects produced responses at the same rate whether performing one task or two simultaneously: the limited capacity to produce responses can be divided between two simultaneously performed tasks. [p. 301]

Pashler also notes [p. 348] that ``Recent results strengthen the case for central interference even further, concluding that memory retrieval is subject to the same discrete processing bottleneck that prevents simultaneous response selection in two speeded choice tasks."

In the section on ``Mental Effort" Pashler reports that ``incentives to perform especially well lead subjects to improve both speed and accuracy", and that the motivation had ``greater effects on the more cognitively complex activity". This is what would be expected if incentives lead to effort that produces increased rapidity of the events, each of which injects mental intention into the physical process.

Studies of sleep-deprived subjects suggest that in these cases ``effort works to counteract low arousal". If arousal is essentially the rate of occurrence of conscious events then this result is what the quantum model would predict.

Pashler notes that ``Performing two tasks at the same time, for example, almost invariably... produces poorer performance in a task and increases ratings in *effortfulness*." And ``Increasing the rate at which events occur in experimenter-paced tasks often increases effort ratings without affecting performance". ``Increasing incentives often raises workload ratings and performance at the same time." All of these empirical connections are in line with the general principle that effort increases the rate of conscious events, each of which inputs a mental intention, and that this resource can be divided between tasks.

Additional supporting evidence comes from the studies of the effect of the conscious process upon the storage of information in short-term memory. According to the physics-based theory, the conscious process merely actualizes a course of action, which then develops automatically, with perhaps some occasional monitoring. Thus if one sets in place the activity of retaining in memory a certain sequence of stimuli, then this activity can persist undiminished while the central processor is engaged in another task. This is what the data indicate.

Pashler remarks that "These conclusions contradict the remarkably widespread assumption that short-term memory capacity can be equated with, or used as a measure of, central resources."[p.341] In the theory outlined here short-term memory is stored in patterns of brain activity, whereas consciousness is associated with the selection of a sub-ensemble of quasi-classical states. This distinction seems to account for the large amount of detailed data that bears on this question of the connection of short-term-memory to consciousness. [p.337-341]

Deliberate storage in, or retrieval from, long-term memory requires focused attention, and hence conscious effort. These processes should, according to the theory, use part of the limited processing capacity, and hence be detrimentally affected by a competing task that makes sufficient concurrent demands on the central resources. On the other hand, ``perceptual'' processing that involves conceptual categorization and identification without conscious awareness should not interfere with tasks that do consume central processing capacity. These expectations are what the evidence appears to confirm: ``the entirety of...front-end processing are modality specific and operate independent of the sort of single-channel central processing that limits retrieval and the control of action. This includes not only perceptual analysis but also storage in STM (short term memory) and whatever may feed back to change the allocation of perceptual attention itself.'' [p. 353]

Pashler describes a result dating from the nineteenth century: mental exertion reduces the amount of physical force that a person can apply. He notes that ``This puzzling phenomena remains unexplained.'' [p. 387]. However, it is an automatic consequence of the physics-based theory: creating physical force by muscle contraction requires an effort that opposes the physical tendencies generated by Process II. This opposing tendency is produced by the quantum Zeno effect, and is roughly proportional to the number of bits per second of central processing capacity that is devoted to the task. So if part of this processing capacity is directed to another task, then the applied force will diminish.

Pashler speculates on the possibility of a neurophysiological explanation of the facts he describes, but notes that the parallel versus serial distinction between the two mechanisms leads, in the classical neurophysiological approach, to the questions of what makes these two mechanisms so different, and what the connection between them is. [p.354-6, 386-7]

After analyzing various possible mechanisms that could cause the central bottleneck, Pashler [p.307-8] says ``the question of why this should be the case is quite puzzling.'' Thus the fact that this bottleneck, and its basic properties, seem to follow naturally from the same laws that explain the complex empirical evidence in the fields of classical and quantum physics means that the theory has significant explanatory power.

## 8. MENTAL ACTION IN NEUROSCIENCE.

Consider an idealized experiment of the following kind. Suppose a human subject is being monitored by devices that measure and record electromagnetic activity in his or her brain on a millimeter spatial scale and millisecond time scale. Suppose the subject is presented with a sequence of paired inputs, with each pair well separated in time from the others. Each pair consists of whispered instruction followed by sensory signal classified as either being in an emotional category E or not being in E. The preceding whispered instruction is either “suppress emotions of type E” or “do not suppress emotions of type E”. If the instrumentation were sensitive enough, and the subject were appropriately conditioned, one would expect in any physics-based model of the brain that the whispered instruction would produce a response in the brain that could be interpreted as establishing a physical “set” that would tend to block, more or less effectively, a second brain response that could be interpreted as a brain correlate of the emotion E.

A measurable property of interest here would be the dependence of the effectiveness of the blocking action upon the time difference between the whispered instruction and the presentation of the emotionally charged item.

The modeling of brain activity would be quite different in the quantum model as contrasted to the purely micro-local mechanical model. In the latter case all experiential/phenomenal psychologically described properties would be excluded in principle except perhaps as names of causally effective patterns of microscopic controlled brain activity. If the whispered instructions are effective, then the mechanical explanation would, in principle, have to follow the local mechanical processing and show how it accounts for the speed and efficacy of the effect of the whispered instruction upon the brain correlate of the emotional response. The blocking action of the whisper-induced brain "set" could be analogous to the mechanical effect of a small force to turn the faucet that controls the surge of water, or of a small biasing of a potential in a radio tube or transistor in controlling a large current.

In a quantum mechanical account of an efficacious blocking of emotion E, the whispered instruction would cause the state S of the appropriately conditioned brain to evolve mechanically, in accordance with Process II, in a way that would produce, first, an operator P(S) that would correspond to a Process I purposeful action of suppressing emotional response E, second, a consent to actualize this purposeful action, and third, a mental effort to keep attention focused on this task. If $\mathrm{Tr}\, P(S)\, S\, P(S)/\mathrm{Tr}\, S$ is close to unity then this action would very likely occur: the pattern of brain activity that blocks the emotional responses of type E would be activated and held in place by the Quantum Zeno Effect.

These are the outlines the logical structures of the two proposed alternative ways of accounting for an empirically observed suppression of the emotional response E. How can a scientist decide between these alternative models?

The key questions one would seek to answer are the rapidity with which the blocking pattern comes into existence after the whispered instruction, the persistence of that blocking pattern, and its effectiveness in standing up against and blocking the emergence of the neural correlate of the emotional response. Can all of these detailed things be reasonably accounted for by a purely mechanical model? Or is the dynamical intervention of the quantum Process I needed?

A study of his kind might seem like the right way to go. But from a theoretical physics point of view the classical approach, though it might sound reasonable at first, is a non-starter. The laws of classical physics break down at the micro-level, and hence the “classical scenario” cannot actually be followed through, without violating the laws of physics: the classical-physics picture evaporates if one tries seriously to use it to describe the kinds of (microscopic ionic) activities that would be crucial to a detailed causal description of brain activity. A realistic “classical description” of the pertinent physical structures (e.g., ions in nerve terminals) simply does not exist. So there is no way to realistically say whether the classical microscopic description can adequately explain the effect of the whisper in blocking the neural correlate of the emotional response. More strongly put, the classical description certainly cannot do the necessary job.

One could, in principle, use the non-local (and non-relativistic) quantum mechanical model invented by David Bohm. That model seems to keep consciousness out of the dynamics. But that model has an intrinsic difficulty in connecting physics to experience. The model introduces supplemental variables, besides the ones used in orthodox quantum theory, to account for the fact that experiences are definite, rather than smeared out superpositions of all possible experiences. But these extra variables would allow experiences to be *too* definite: these knowledge-fixing variables would permit us to have knowledge that orthodox quantum theory seems to show is impossible for knowledge-acquiring agents to acquire. Thus Bohm’s way to relate human experiences to human brains is even more problematic than the ill-defined classical way. Indeed, Bohm turned to orthodox quantum theory in order to connect his physical variables to the human experiences they are supposed to determine. This tactic emphasizes the fact that no scientific theory is complete unless it ties itself to human experience. Orthodox quantum theory builds this essential connection into the dynamics, whereas no other form of physical theory deals seriously with the problem of tying the physical features of the theory to conscious human thoughts.

## 9. RECENT VIEWS.

A tremendous burgeoning of interest in the problem of consciousness has occurred during the past few years. The grip of the behaviorists who sought to banish consciousness from science has finally been broken. This shift is ratified by the recent appearance of a special issue of Scientific American entitled “The Hidden Mind.” The lead article, written by Antonio Damasio, begins with the assertion: “At the start of the new millennium, it is apparent that one question towers above all others in the life sciences: How does the set of processes we call mind emerge from the activity of the organ we call brain?” He notes that some thinkers “believe the question to be unanswerable in principle’’ while “For others, the relentless and exponential increase in knowledge may give rise to the vertiginous feeling that no problem can resist the assault of science if *only the science is right* and the techniques are powerful enough.” (my emphasis) He notes that “The naysayers argue that exhaustive compilation of all these data (of neuroscience) adds up to *correlates* of mental states but to nothing resembling *an actual mental state.*” (his emphasis) He adds that: “In fact, the explanation of the physics related to biological events is still incomplete” and states that “the finest level of description of mind … might require explanation at the quantum level.” Damasio makes his own position clear: “I contend that the biological processes now presumed to correspond to mind in fact *are* mind processes and will be seen to be so when understood in sufficient detail.”

With “biological processes” understood to be quantum processes, including the key Process I, I agree that those biological processes are mind processes. That is because those biological brain processes demand, for the reasons described in earlier chapters, the application of quantum physics, and that makes *feelings* critical and non-redundant components of these biological processes.

The possibility that quantum physics might be relevant to the connection between conscious process and brain process was raised also by Dave Chalmers, in his article *The Puzzle of Consciousness*, However, he effectively tied that possibility to a proposal put forth by Roger Penrose, and, faulting that particular approach, rejected the general idea.

The deficiency of Penrose's approach identified by Chalmers is that it fails to bring in consciousness: it is about certain brain processes that may be related to consciousness, but "…the theory is silent about how these processes might give rise to conscious experience. Indeed, the same problem arises with any theory of consciousness based only on physical processing." That final conclusion is based, however, on the presumption that physical brain processes can be described in a way that leaves experiences out. But, for the reasons already described, Process I, hence experiences, plays an irreplaceable dynamical role in physical brain processing.

Chalmers goes on to expound upon the "explanatory gap" between theoretical understanding of the behavioral and functional aspects of brain process and an explanation of how and why the performance of those functions should be accompanied by conscious experience. However, the notion that such a "gap" exists depends upon the presumption that a valid understanding or conception of physical brain behavior can be divorced from its connection to the associated conscious experiences. But the notion that such a separation is possible arises only from the inadequate-in-this-regard classical model.

The confounding of reality itself with the caricature of it suggested by the work of Descartes and Newton has derailed the philosophy of science, the philosophy of mind, moral philosophy, and aesthetics for more than three centuries, by presenting it with an irresolvable dilemma based on a conception of nature that is profoundly wrong at precisely the critical point. This flawed view still retains its blinding effect on the thinking of even those philosophers who absolutely reject that dualistic view. For example, Daniel Dennett, one of the most out-spoken critics of classical Cartesian dualism, says that his own thinking rested on the idea that "a brain was always going to do what it was caused to do by current, local, mechanical circumstances." But by making that judgment he tied his thinking to *the physical half of Cartesian/Newtonian dualism*, or its child, classical physics, and thus was forced in his book "Explaining Consciousness" to leave consciousness out, as he himself admits, but tries to justify, at the end. By thus accepting the fundamentally erroneous classical-physics understanding of brain processes, instead of the view offered by modern science, Dennett cuts himself off from any possibility of validly explaining consciousness.

Many important features of the von Neumann approach being described here can be brought out by contrasting them with the contrary properties of a vaguely similar proposal put forth by Roger Penrose and Stuart Hameroff. Their theory ties the transitions S→S' occurring in human brains to general relativity and to gravitational forces in the brain.

A first essential difference between the present proposal and that of Penrose and Hameroff is that their theory depends on establishing macroscopic quantum coherence over an extended portion of the brain, whereas the theory being described here does not. Most physicists deem it highly unlikely that such large-scale coherence could be sustained in a warm, wet, living brain.

A second difference is that their theory depends on the complex question of quantum gravity, which is currently not under good theoretical control, whereas the theoretical ideas that are the basis of the present approach are the fundamental mathematical principles of quantum theory, which, thanks to the work of John von Neumann, are under much better control.

The third difference is that the justification that Penrose gives for believing that quantum theory has something to do with human consciousness is a very much disputed argument that claims to deduce from (1), the fact that mathematicians construct proofs that they believe to be valid, and (2), some deep mathematical results due to Kurt Godel, the conclusion that conscious thought must involve quantum theory. But in the von Neumann approach the relevance of consciousness arises not from any such complex argument, but rather directly from its connection to Process I, which is a basic feature of orthodox quantum theory.

The forth difference is the fact, already emphasized by Chalmers, that Penrose's theory of consciousness turns out to be about a brain transition, but is silent about how that brain activity might give rise to conscious experiences, whereas the present work is directly about the relationship of brain processes to conscious experiences.

Francis Crick and Christof Koch begin their essay *The Problem of Consciousness* with the assertion: “The overwhelming question in neurobiology today is the relationship between the mind and the brain.” But after a brief survey of the difficulties in getting an answer they conclude that “Radically new concepts may indeed be needed---recall the modifications in scientific thinking forced on us by quantum mechanics. The only sensible approach is to press the experimental attack until we are confronted with dilemmas that call for new ways of thinking.”

However, the two cases are extremely dissimilar. The switch to quantum theory was forced upon us by the fact that we had a very simple system---consisting of a single hydrogen atom interacting with the electromagnetic field---that was so simple that it could be exactly solved by the methods of classical physics, but the calculated answer did not agree with the empirical results. There was no conceptual problem. It was rather that precise computations were possible, but gave wrong answers. Here the problem is reversed: precise calculations of the dynamical brain processes associated with conscious experiences are not yet possible, and hence have not revealed any mismatch between theory and experiment. However, ithe *concepts of classical physics* that many neurobiologists want to use that are clearly inadequate: they lack the conceptual ingredients needed to account for conscious experience. Dave Chalmers recognizes this conceptual difficulty, and concludes that experimental work by neurobiologists is not by itself sufficient to resolve of *The Puzzle of Conscious Experience*: better concepts are also needed. He suggests that the stuff of the universe might be *information*, but then rejects the replacement of classical physical theory, which is based on material substance, by quantum theory, which builds (its conception of) nature out of a non-substantive stuff that can be characterized as information encoded in a space-time non-material structure. Classical physics, although known to be inadequate for describing systems that depend in important ways on microscopic ionic processes, maintains its iron grips on the minds not only of many neuroscientists, but also on the minds of young philosophers.

John Searle is perhaps the strongest contemporary voice calling for a forthright acknowledgement of both the existence of the subjective realities, and also the need to explain them, rather than trying to explain them away. His most recent views mesh well with the quantum approach developed here.

I shall use as my source Searle's article in the Journal of Consciousness Studies, which is based on his talk at the Tucson 2000 conference on Consciousness. This presentation seems to me to represent his best effort to come to grips with the problem.

Searle reiterates his longtime themes:

1. Consciousness is a real biological phenomenon.
2. It consists of inner, qualitative, subjective, unified states of sentience, awareness, thoughts and feelings.
3. This unified field of conscious subjective awareness is not reducible to any third-person phenomena.
4. All of our conscious states are caused by lower-level neuronal processes in the brain.
5. All of our conscious states are themselves features of the brain.

If one were to accept the classical-physics conception of the brain then there would appear to be a conflict between claims 3 and 5. For if a brain were a conglomeration of particles, which, as the objective elements of nature, are third-person entities, and conscious states are features of these conglomerations, as asserted by claim 5, then consciousness seems to be reduced to third-person phenomena, in violation of claim 3. However, if one accepts the quantum idea that the states of consciousness characterized in properties 1, 2, and 3, are first-person subjective features of the brain, which is an informational structure that combines distinct first-person and third-person informational features, then this conflict is resolved. Searle's position needs quantum theory in order to become internally consistent.

Later on, Searle introduces "psychological processes" by observing that people sometimes give 'reasons' for acting as they do. But he notes that these 'reasons' are not always conclusive, or sufficient to entail the actions they promote. He wishes to consider the possibility that although the psychological processes may be indeterministic, the underlying “neurobiological process” is deterministic. He then says that psychological indeterminism with neurobiological determinism---

“is intellectually unsatisfying because it is a modified form of epiphenomenalism. It says that the psychological processes of decision making really do not matter. The entire process is deterministic at the bottom level, and the idea that the top level has an element of freedom is simply a systematic illusion. … The bodily movements would be exactly the same regardless of how these processes occurred.

“Maybe that is how it will turn out, but if so the hypothesis seems to me to run against everything we know about evolution. It would have the consequence that the incredibly elaborate, complex, sensitive and ---above all---biologically expensive system of human and animal conscious rational decision-making would actually make no difference whatever to the life and survival of the organism. Epiphenomenalism is a possible thesis, but it is absolutely incredible, and if we seriously accept it, it would make a change in our world view, that is, in our conception of our relations to the world, more radical than any previous change, including the Copernican Revolution, Einsteinian relativity theory and quantum theory.”

The sort of epiphenomenal consciousness that Searle is considering, and finds incredible, is what necessarily arises from a classical-physics conception of the brain. But quantum theory gives consciousness a causal power that is outside the control of the bottom-level local deterministic laws that are the quantum counterparts of the classical laws of motion. The causal power of consciousness arises from the way that consciousness fills a *causal gap* in those bottom-level laws. This lacuna is filled by conscious causal agents, acting via the ‘top-down’ Process I.

Semir Zeki, a leading neuroscientist in the study of the diverse brain processes connected to vision, writes about the process of abstraction associated with the creation of works of art, analyzing the treatments of “love” in the poetry of Dante, the sculptures of Michelangelo, and the opera *Tristan and Isolde* by Wagner. He focuses on the abstracting powers of the various separate processing modules but says: "There must therefore be some other process that unifies and binds what these different areas have processed, a problem that is currently under study. The point that I emphasize here is that the unification and binding come after the abstractive processes, which constitute the first step in the knowledge-acquiring system."

This view of man as a knowledge-acquiring system is in perfect accord with quantum theory.

## 10. KNOWLEDGE, INFORMATION, AND ENTROPY

The book *John von Neumann and the Foundations of Quantum Physics* contains a fascinating and informative article written by Eckehart Kohler entitled "Why von Neumann Rejected Carnap's Dualism of Information Concept." The topic is precisely the core issue before us: How is knowledge connected to physics? Kohler illuminates von Neumann's views on this subject by contrasting them to those of Carnap.

Rudolph Carnap was a distinguished philosopher, and member of the Vienna Circle. He was in some sense a dualist. He had studied one of the central problems of philosophy, namely the distinction between *analytic* statements and *synthetic* statements. (The former are true or false by virtue of a specified set of rules held in our minds, whereas the latter are true or false by virtue their concordance with physical or empirical facts.) His conclusions had led him to the idea that there are two different domains of truth, one pertaining to logic and mathematics and the other to physics and the natural sciences. This led to the claim that there are "Two Concepts of Probability," one logical the other physical. That conclusion was in line with the fact that philosophers were then divided between two main schools as to whether probability should be understood in terms of abstract idealizations or physical sequences of outcomes of measurements. Carnap's bifurcations implied a similar division between two different concepts of information, and of entropy.

In 1952 Carnap was working at the Institute for Advanced Study in Princeton and about to publish a work on his dualistic theory of information, according to which epistemological concepts like information should be treated separately from physics. Von Neumann, in private discussion, raised objections, and Pauli later wrote a forceful letter, asserting that "I am quite strongly opposed to the position you take." Later he adds "I am indeed concerned that the confusion in the area of the foundations of statistical mechanics not grow further (and I fear very much that a publication of your work in its present form would have this effect)."

Carnap's view was in line with the Cartesian separation between a domain of real objective physical facts and a domain of ideas and concepts. But von Neumann's view, and also Pauli's, linked the probability that occurred in physics, in connection with entropy, to *knowledge*, in direct opposition to Carnap's view that epistemology (considerations pertaining to knowledge) should be separated from physics. The opposition of von Neumann and Pauli significantly influenced the publication of Carnap's book.

This issue of the relationship of knowledge to physics is the central question before us, and is in fact the core problem of all philosophy and science. In the earlier chapters I relied upon the basic insight of the founders of quantum theory, and upon the character of quantum theory as it is used in actual practice, to justify the key postulate that Process I is associated with knowing, or feeling. But there is also an entirely different line of justification of that connection developed in von Neumann's book, *Mathematical Foundations of Quantum Mechanics*. This consideration, which strongly influenced his thinking for the remainder of his life, pertains to the second law of thermodynamics, which is the assertion that entropy (disorder, defined in a precise way) never decreases.

There are huge differences in the quantum and classical workings of the second law. Von Neumann's book discusses in detail the quantum case, and some of those differences. In one sense there is no nontrivial objective second law in classical physics: a classical state is supposed to be objectively well defined, and hence it always has probability one. Consequently, the entropy is zero at the outset and remains so forevermore. Normally, however, one adopts some rule of "coarse graining" that destroys information and hence allows probabilities to be different from unity, and then embarks upon an endeavor to deduce the laws of thermodynamics from statistical considerations. Of course, it can be objected that the subjective act of choosing some particular coarse graining renders the treatment not completely objective, but that limited subjective input seems insufficient to warrant the claim that physical probability is closely tied to knowledge.

The question of the connection of entropy to the *knowledge and actions of an intelligent being* was, however, raised in a more incisive form by Maxwell, who imagined a tiny "demon" to be stationed at a small doorway between two large rooms filled with gas. If this agent could distinguish different species of gas molecules, or their energies and locations, and slide a frictionless door open or closed according to which type of molecule was about to pass, he could easily cause a decrease in entropy that could be used to do work, and hence to power a perpetual motion machine, in violation of the second law.

This paradox was examined Leo Szilard, who replaced Maxwell's intelligent "demon" by a simple idealized (classical) physical mechanism that consumed no energy beyond the apparent minimum needed to 'recognize and responded differently to' a two-valued property of the gas molecule. He found that this rudimentary process of merely 'coming to know and respond to' the two-valued property transferred entropy from heat baths to the gaseous system in just the amount needed to preserve the second law. Evidently nature is arranged so that what we conceive to be the purely intellectual process of coming to know something, and acting on the basis of that knowledge, is closely linked to the probabilities that enter into the constraints upon physical processes associated with entropy.

Von Neumann describes a version of this idealized experiment. Suppose a single molecule is contained in a volume V. Suppose an agent comes to know whether the molecule lies to the left or to the right of the center line. He is then in the state of being able to order the placement of a partition/piston at that line and to switch a lever either to the right or to the left, which restricts the direction in which the piston can move. This causes the molecule to drive the piston slowly to the right or to the left, and transfer some of its thermal energy to it. If the system is in a heat bath then this process extracts from the heat bath an amount 'log 2' of entropy (in natural units).

Thus the *knowledge* of which half of the volume the molecule was in is converted into a decrement of “log 2’ units of entropy. In von Neumann’s words, “we have exchanged our knowledge for the entropy decrease k log 2.” (k is the natural unit of entropy.)

What this means is this: When we conceive of an increase in the “knowledge possessed by some agent” we must not imagine that this knowledge exists in some ethereal kingdom, apart from its physical representation in the body of the agent. Von Neumann’s analysis shows that the change in knowledge represented by Process I is quantitatively tied to the probabilities associated with entropy.

Among the many things shown by von Neumann are these two:

(1) The entropy of a system is unaltered when the state of that system is evolving solely under the governance of Process II.
(2) The entropy of a system is never decreased by any Process I event.

The first result is analogous to the classical result that if an objective “probability” were to be assigned to each of a countable set of possible classical states, and the system were allowed to evolve in accordance with the classical laws of motion then the entropy of that system would remain fixed.

The second result is a nontrivial quantum second law of thermodynamics. Instead of coarse graining one has Process I, which in the simple ‘Yes-No’ case converts the prior system into one where the question associated with the projection operator P has a definite answer, but only the *probability* associated with each possible answer is specified, not an answer itself.

One sees, therefore, why von Neumann rejected Carnap’s attempt to divorce knowledge from physics: large tracts in his book were devoted to establishing their marriage. That work demonstrates the quantitative link between the increment of knowledge or information associated with a Process I event and the probabilities connected to entropy. This focus on Process I allowed him to formulate and prove a quantum version of the second law. In the quantum universe the rate of increase of entropy would be determined not by some imaginary and arbitrary coarse graining rule, but by the number and nature of objectively real Process I events.

Kohler discusses another outstanding problem: the nature of mathematics. At one time mathematics was imagined to be an abstract resident of some immaterial Platonic realm, independent in principle from the brains and activities of those who do it. But many mathematicians and philosophers now believe that the process of doing mathematics rests in the end on mathematical intuitions, which are essentially aesthetic evaluations.

Kohler argues that von Neumann held this view. But what is the origin or source of such aesthetic judgments?

Roger Penrose based his theory of consciousness on the idea that mathematical insight comes from a Platonic realm. But according to the present account each such illumination, like any other experience, is represented in the quantum description of nature as a picking out of an organized state in which diverse brain processes act together in an harmonious state of mutual support that leads on to feedbacks that sustain the structure by recreating it with slight variations  A mathematical illumination is a grasping of an *aesthetic* quality of order in the quantum state of the agent's brain/body. Every experience of any kind is fundamentally like this: it is a Process I grasping of a state of order that tends recreates itself in a slightly varied form.

This notion that each Process I event is a felt grasping of a state in which various sub-processes act in concert to produce an ongoing continuation of itself provides a foundation for answering in a uniform way many outstanding philosophical and scientific problems. For example, it provides a foundation for a solution to a basic issue of neuroscience, the so-called "binding problem". It is known that diverse features of a visual scene, such as color, location, size, shape, etc.  are processed by separate modules located in different regions of the brain. This understanding of the Process I event makes the felt experience a grasping of a non-discordant quasi-stable mutually supportive combination of these diverse elements as a unified whole. To achieve maximal organizational impact this event should provide the conditions for a rapid sequence of re-enactments of itself. Then this conception of the operation of von Neumann's process I provides also an understanding of the capacity of an agent's thoughts to control its bodily behavior. The same conception of Process I provides also a basis for understanding both artistic and mathematical creativity, and the evolution of consciousness in step with the biological evolution of our species. These issues all come down to the problem of the connection of knowings to physics, which von Neumann's treatment of entropy ties to Process I.

Kohler quotes an interesting statement of von Neumann, but then draws from it conclusions about von Neumann's views that go far beyond what von Neumann actually said.

Von Neumann points out that in classical mechanics one can solve the problem of motion either by solving differential equations (the local causal mechanistic approach) or by using a global least action (or some other similar) approach. This latter method can be viewed as "teleological" in the sense that if initial and final conditions are specified then the principle of least action specifies the path between them. He goes on to say that he is:

"not trying to be facetious about the importance of keeping teleological principles in mind when dealing with biology; but I think one hasn't started to understand the problem of their role in biology until one realizes that in mechanics, if you are just a little bit clever mathematically, your problem disappears and becomes meaningless. And it is perfectly possible that if one understood another area then the same thing might happen."

The pertinent "other area" is psychology, or the problem of mind.

The first point is that von Neumann's statement is very cautious: he says that it is "perfectly *possible* that *if* one understood another area the same thing *might* happen." There are three weak links: "possible","if", and "might."

Kohler's conclusion is far less cautious. He follows the above quotation with the assertion:

"Here von Neumann warns biologists against overstressing goal-directed activity since this can always be reformulated *causally*."

Von Neumann said no such thing. He merely points out that in classical mechanics certain global least action principles are equivalent to local causal mechanistic rules. That falls far short of claiming that *all* goal-directed activity can be expressed in least-action terms, or that in *non-classical* cases such a least-action formulation would necessarily be equivalent to a local causal mechanism. Von Neumann recognizes this as a possibility, not a necessity.

In quantum physics the Process II part of the dynamics is derived from the quantization of the classical law. Hence it might be contended that *for this Process II part of the dynamics* an equivalence holds between "teleological" and "causal" formulations. But the connection to mind involves Process I. It is far from obvious that the equivalence found in classical mechanics will carry over to Process I. In the first place, Process I involves non-local operators P, and that alone would appear to block reduction to local causation. In the second place, Process I drops out of the dynamics when one goes to the classical limit, which is the limit in which all effects involving Planck's constant are neglected. Hence Process I is, in this sense, non-classical or anti-classical. Hence there is no reason to believe that equivalences occurring in classical physics will carry over to Process I. Such a connection "might possibly" hold, but it is surely not required to hold by anything we know today.

Kohler goes on to state that:

"Based on his general approach, one may say von Neumann was a psycho-physical reductionist who thought human intelligence could in principle be presented and explained on a physical level --- in particular, neurologically, in terms of nerve nets. Between the physiology of nerves and the physics of computer devices von Neumann recognized no difference in functional capacity."

That last statement seems tremendously at odds with the conclusions of von Neumann's final work, "The Computer and the Brain," which emphasized the huge differences between brains and computers. But, that point aside, the fact that von Neumann did much work on classically describable computers does not imply that he was committed to the view that *human intelligence* could be understood in classical terms. Von Neumann may indeed have not excluded that possibility, but I doubt that any statement of his shows him to be committed to the position that human intelligence, and, more importantly, his Process I, can be explained in local mechanistic terms. The statement quoted above certainly fails to justify such a conclusion.

## 11. OTHER INTERPRETATIONS.

Some physicists are dissatisfied with von Neumann's formulation of quantum theory, and have put forth alternative proposals. The origin of their dissatisfaction is the entry of our streams of conscious thoughts into basic physical theory. However, our conscious thoughts are certainly parts of reality, and are, indeed, the very parts of reality whose existence is least in doubt. Every part of reality probably has some effect upon the whole. Hence it would seen not only natural, but also imperative, that the laws of nature should provide a way for our minds to influence nature, and, in particular, the flow of events in our brains. Thus the incorporation by quantum theory of mental events into brain dynamics would appear to be an important step in the right direction. Nevertheless, some conservative scientists believe that science should cling to the nineteenth century ideal, which specifies that the workings of brains can be completely described, at least in principle, without considering idea-like realities, which are deemed to be either redundant arrangements of mindless realities, or causally inert bystanders.

In this connection Kathryn Blackmond Laskey of George Mason University wrote:

*I would appreciate your answering a question I have.*

*There is much disagreement in the literature about the reduction process and how it works, including controversy over whether there is any such thing as reduction. I have read numerous statements from physicists that measurement involves inter action of a quantum system with its environment, and is (it is asserted) therefore "nothing but" Schrodinger evolution on a larger system.*

It has, indeed, been sometimes claimed that the interaction with the environment solves the measurement problem, However, the principal protagonists of this notion (e.g., W. Zurek, D. Zeh, & E. Joos) do not, I believe, claim that all of the essentials of that proposal have really been worked out. I have argued [Can. J. Phys. 2002: The basis problem in many-worlds theories, vol. 80, pp.1043-105] that important aspects have in fact *not* been worked out, and that the gaps are sufficiently serious to block, at the present time, the claim that the Schroedinger equation alone (and this includes the environmental decoherence) is actually sufficient, by itself, to tie the theory to well-defined predictions pertaining to human experiences. Such predictions are required for the theory to be scientifically meaningful, and they are obtained in the von Neumann formulation only by introducing the Process I dynamical interventions, which are explicitly tied to idea-like realities.

The reason, in brief, why an extra dynamical process is needed is this: If the universe has been evolving since the big bang solely under the influence of the Schroedinger equation---i.e., Process II---then every object and every human brain would be by now, due to the uncertainty conditions on the original positions and velocities, represented in quantum theory by an amorphous continuum: the center-point each object would not lie at a particular point, or even be confined to a small region, but would be continuously spread out over a huge region; and, likewise, the state of the brain every observer of this object would be a smeared out conglomeration of many different classical-type brains, one corresponding to each of the allowed center-points in this big region. That is, if a human person were observing an object, whose center-point, as specified by its quantum state, were spread out over a region several meters in diameter, then the state of the brain of that person would have, for each of these different locations, a part, corresponding to the observer's seeing the object in that location. If each of these parts of the brain were accompanied by the corresponding *experience*, then there would exist not just one experience corresponding to seeing the object in just one place, but a *continuous* aggregation of experiences, with one experience for each of the possible locations in the large region. Thus this theory is often called, quite rightly, a "many-minds" interpretation:

John Doe evolves into a smeared out continuum of John Doe's each having an experience different from every other one.

In order to extract from quantum theory a set of predictions pertaining to human experiences, and hence to give empirical meaning to the theory, this smeared out collection of different brain structures must be resolved in a very special way into a collection of *discrete* parts, each corresponding to one possible experience. This *discreteness condition* is a technical point, but it constitutes the essential core of the measurement problem. Hence I must explain it!

Evolution according to the Schroedinger equation (Process II) generates in general, as I have just explained, a state of the brain of an observer that is a smeared out continuum of component parts, each corresponding to a different possible experience. One cannot assign a nonzero probability to each one of such a continuum of possibilities, because the total probability would then be infinity, instead of one (unity). However, the mathematical rules of quantum theory have a well-defined way to deal with this situation: they demand that the space of possibilities be divided in a certain very restrictive way into a countable set of alternative possibilities, where a *countable set* is a set that can be *numbered* (i.e., placed in one-to-one correspondence with the integer numbers 1, 2, 3, … .). The need to specify a particular *countable set* of parts is *the essential problem* in the construction of a satisfactory quantum theory. But then the technical problem that the dissenters face is this: How does one specify a satisfactory particular *countable* set of *discrete* possibilities from Process II alone, when Process II is a *continuous* local process that generates a structure that continuously connects components that correspond to very different experiences, and hence must belong to different members of the countable set? The problem is essentially the same as saying that a process that generates only a circle generates also some particular point on that circle: an extra property is imputed to a process that lacks that property.

In the Copenhagen formulation of quantum theory this selection of a preferred set of discrete states is achieved by a *choice on the part of the experimenter.* The measuring device, set in a particular place by the experimenter, selects some particular part of the state of the observed system that corresponds to some particular kind of experience. In this simple case the countable set has just two elements, one specified by the projection operator P, the other specified by the projection operator (I-P). In this way the basic problem of specifying a countable set of discrete parts is solved by bringing into the theory *a choice on the part of the experimenter*. Von Neumann solves this discreteness problem in the same way, and gives this selection process the name Process I.

Einstein posed essentially the same problem in a clear way. Suppose a pen that draws a line on a moving scroll is caused to draw a blip when a radio-active decay is detected by some detector. If the only process in nature is Process II, then the state of the scroll will be a blurred out state in which the blip occurs in a continuum of alternative possible locations. Correspondingly, the brain of a person who is observing the scroll will be in a smeared out state containing a continuously connected collection of components, with one component corresponding to each of the possible locations of the blip on the scroll. But how does this smeared out continuously connected state of the brain get divided by Process II alone into components to which well-defined probabilities can be assigned? The normal rules cover only the cases in which there is a specified countable collection of distinct possibilities.

A key feature of the orthodox approach is the "empirical fact" that experimenters can have definite thoughts, and that they can therefore place the devices in definite locations. Thus it is the discreteness of the *choice* made by the experimenter that resolves the discreteness problem. But an experimenter represented by a state governed solely by the Schroedinger equation has nothing discrete about him: his brain is a continuous smear with no dynamically defined dividing lines.

The founders of quantum theory (and von Neumann) recognized this basic problem of principle, and in order to resolve it went to a radical and revolutionary extreme: they introduced human experimenters with efficacious free choices into the physical theory. This was a giant break from tradition. But the enormity of the problem demanded drastic measures. Because such powerful thinkers as Wolfgang Pauli and John von Neumann found it necessary to embrace this revolutionary idea, anyone who claims that this unprecedented step was wholly unnecessary certainly needs to carefully explain why. But this has not been done. Rather, the environmental decoherence effect has been taken to be a panacea. However, that well understood effect appears to have no significant impact on the discreteness problem.

[[This issue is a technical one that lies outside the scope of this work. But for the benefit of mathematically inclined reader I include this parenthetical remark. The physical system S can represented by a "matrix" S(*l,l'* ), where *l* specifies a location for every "particle" in the classical conception of the system, and so does *l'*. The "diagonal" elements are those for which *l* = *l'*. The far off-diagonal elements are suppressed by the environmental decoherence effect, but the slightly off-diagonal elements remain generally nonzero, and they lock the whole near-diagonal structure together. The region where S(*l,l*) is significantly different from zero remains large, even after the effects of interaction with the environment are taken into account. It is not broken up by the continuous action of Process II into a collection of different, isolated regions that could be associated with different experiences. But then the way in which a countable set of discrete states is singled out must evidently depend on something besides Process II, and the quantum state whose evolution it generates. In any case, the way that particular experiences are assigned finite probabilities, given only Process II, needs to be worked out and described in detail by anyone who claims that the Schroedinger evolution, Process II alone, is sufficient.

Actually, the problem is technically much more difficult than the above brief sketch indicates. The real situation involves a space of an infinite number of dimensions, but the discreteness problem can be illustrated in a simple model having just two dimensions. Take a sheet of paper and put a point on it. (Imagine that your pencil is infinitely sharp, and can draw a true point, and perfectly straight lines of zero width.) Start drawing straight lines out from the point in different directions. With an infinitely sharp pencil your could draw lines in different directions for billions of years, at one line a femto-second, and not come even close to using up the set of all possible directions. However, the rules of quantum theory demand in this two dimensional case that some one particular direction, (together with the one perpendicular to it) be picked out from this continuous infinity of possible directions as preferred to all the others. But how is such an incredibly precise choice determined by this continuous Process II?

This is the famous "basis problem." which was solved by the founders, and by von Neumann, by invoking the choice on the part of the experimenter. Although bringing in the human experimenter in this special way is certainly very contrary to the ideas of classical physics, the notion that our streams of consciousness play some important dynamical role in the determination of our behavior is not outlandish: it is what almost anyone would naturally expect.

This description of the discreteness problem is rather concise, and perhaps too abstract to really hit home to a non-physicist reader. What is really wrong, you may still ask, with going along with just the Process II alone, and the amorphous continuous state S(*l,l'* )? Why is this choice of a discrete basis so essential? Let me explain this in more concrete terms.

If you have just a countable set of states then you could, for example, assign probability ½ to the first state, probability ¼ to the second state, probability 1/8 to the third, and so on, and the total probability will add to one (unity), as a sum of probabilities should. But if the probability S(*l.l*) is a continuous function of *l*, as it would be if only process II were present, and there were a distinct experience for each value of l, and S(*l,l*) were non-zero for some value of *l* , then S(l,l) would necessarily be larger than some (perhaps very tiny) non-zero number, say e, in some finite region. (This follows from the continuousness of S(l,l), and the fact that S(l,l) must be a positive number or zero.) But there are an infinite number of possible values of l in any finite interval, and if each one represents a real existing different experience, then the total probability for an experience to occur would be at least infinity times e, or infinity.

The main idea of quantum theory is to use a generalization of the theorem of Pythagoras to resolve this problem. That theorem says that the sum of the squares of the two shorter sides of a right triangle is equal to the square of the longer side. This rule generalizes to a figure in a space of an infinite number of dimensions in the following way: If a displacement of unit length is a sum of a set of displacements *each perpendicular to every other one*, then the sum of the squares of the lengths of these displacements is one (unity). Using this law we can guarantee that probabilities of the different experience possible in any given situation will add to unity (i.e., to one) if we assert that the different possible experiences correspond to *a set of mutually perpendicular directions in the space of possibilities.* But these preferred directions are an infinitely small fraction of the set of all possibilities. So the main problem in principle in the construction of a satisfactory quantum theory is: How are these special directions in the space of all possibilities singled out from all the others?

The conclusion of the founders, of von Neumann, and of myself, is that these special directions cannot be selected by Process II alone. Any contrary claim needs to be spelled out in detail.]]

Kathryn went on to say:

*Bohm and Hiley say this* (that there is no collapse or reduction*) in describing their hidden variable theory.*

Bohm's pilot-wave model is another attempt to add onto the raw theory an extra process, in order to tie the raw theory to human experiences in a quantitative way.

The main objection to that theory is that, in spite of many years of intensive effort, it has not been generalized to cover relativistic cases involving particle creation and annihilation.

I once asked Bohm how he answered Einstein's charge that his model was "too cheap". He said that he agreed! And notice that the last two chapters of his book with Hiley tries to go beyond this model. David Bohm, like myself, saw the need to deal more adequately with consciousness, and he wrote several papers on the subject. At the present time Hiley is working on ideas that go far beyond the concepts used in the old pilot-wave model. I do not think any physicist actually working in the area would claim that the pilot-wave model exists today in the relativistic domain.

Kathryn continued:

*Others also say this, including people who don't subscribe to the Bohm pilot wave + particle ontology, such as Carver Mead in "Collective Electrodynamics," who gives a fairly well worked-out example of a quantum oscillator jumping an energy level, and how this can be explained by systems that briefly cross phases, exchange energy, then go out of phase again.*

Quantum theory explains very well how information is continuously transferred to measuring devices. But those beautiful descriptions are the *basis* of the measurement problem, not the solution. They do not explain how some object whose location (as represented by the quntum state) is spread out over meters is experienced as being located close to a point, and with some well defined probability.

Kathryn continues:

*R. Mirman says "Wavefunctions don't collapse, oversimplifications do... Perhaps what collapses is not the statefunction, but common sense... Discontinuity cannot be true, and it is not. But carelessness unfortunately can be true and too often is, and certainly can make discontinuity appear true." He goes on to amplify: "If for example we consider an object striking a screen forming a spot, the statefunction of the system after the formation, the product of that of the struck atom plus all objects attracted to it and the scattered object, is found from the initial one using Schrodinger's equation, and if so found would be seen to vary continuously. In principle it is possible to calculate final (perhaps extremely complicated) statefunctions from initial ones, and the entire transformation from one statefunction to another is completely continuous. Never is there a sudden change or collapse. Any such appearances result from ignoring the (continuous) intermediate stages by regarding these as happening instantaneously."*

Quite true! If Process II is the whole story then there never is a sudden change or collapse! That’s the problem! The Schroedinger equation generates only continuous changes. But the continuousness of that Process II evolution is closely tied to the fact that in a universe evolving exclusively via the Schroedinger Equation, (i.e., Process II) ever since the big bang, the detector is everywhere, instead of somewhere, and the observer's brain is a smeared out continuum encompassing all possibilities. The continuousness stressed by Mirman is the problem, not the solution.

Once, long ago, I characterized the many-worlds solution as shifting the whole measurement problem onto the mind-brain problem, about which it says nothing. For the theory to be empirically meaningful it must be tied to probabilistic statements about alternative possible human experiences. But the smeared-out state of the brain does not cleanly separate vectors from other vectors that differ from them by very tiny amounts. But then what principle, involving nothing but the evolving amorphous state of the universe, can separate the space of brain states into orthogonal subspaces, such as those defined by P and (I-P), associable with different experiences?

I do not claim that this problem has no solution. But Mirman's observation that a world evolving according to the Schroedinger equation alone is evolving continuously does not *solve* the measurement problem: it *creates* the measurement problem. Certainly, Heisenberg and Pauli, and von Neumann, understood very well that a world evolving according to a universally valid Schroedinger equation would evolve continuously. And they also realized that this did not solve the measurement problem. I have absolutely no doubt that von Neumann understood very well also the essential features of environmental decoherence: the basic ideas are all clearly displayed in his work. Yet in order to get an empirically meaningful theory he brought in Process I.

As the final example of a non-orthodox interpretation I mention the work of Ghirardi, Rimini, Weber, and Pearle. Unlike the Everett many-worlds and Bohm-deBroglie pilot-wave proposals this GRWP approach admits “collapse events” that abruptly reduce the state of the universe to a new form, independently of the existence of observers. These collapses are random, and are controlled not by human feelings, but rather by parameters that must be carefully adjusted so as to keep the predictions in line with those of the orthodox theory to within experimental error. But why should nature have delicately selected these parameters so as to make the theory virtually undistinguishable from the orthodox theory, which has no analogous free parameters. And how is that physics tied to experience?

## 12. PSYCHO-PHYSICS

Scientists are free to choose which concepts they take as basic in their endeavor to describe the structure of human experience. Isaac Newton took the point-like idealizations of our visual experiences of distant planets and small physical objects. This is a highly restrictive choice because it leaves out most types of human experience, such as colors, sounds, pains, efforts, evaluations, etc.

Bohr, Pauli, Heisenberg, and the other founders of quantum theory broke with Newton and took action-choosing and knowledge-acquiring human agents as fundamental. Their formulation is the one used in practical work in physics, and there is little likelihood that this will change in physics. However, in other fields, including neuroscience, psychology, and philosophy of mind, many researchers still cling to Newton's ideas, even though they are known to fail in principle for systems---such as brains---whose activities depend sensitively on the detailed behaviors of ions.

Living systems were explicitly excluded by Bohr from the domain of applicability of Copenhagen quantum theory. That limitation was removed by von Neumann's reformulation. All other contenders are, I believe, plagued with problems that can be interpreted as stemming from the failure to adequately incorporate the psychological realities pertinent to science into the physical theory.

Scientists in different fields are to some extent free to use concepts that appear to work for them. On the other hand, many of the greatest advances in science have come from unifying the treatments of different realms of phenomena, and we are now engaged a great scientific endeavor to unify the neurophysiological and psychological aspects of the thinking brain.

From an empirical perspective the most reasonable approach to this project would seem to be to take as basic the empirically accessible realities, namely our thoughts, on the one hand, and, on the other hand, the knowledge that we gain as the knowledge-acquiring agents of contemporary physical theory. But the inertia of nineteenth century science is so great that this approach is often discarded in favor of the old idea that “all is matter.”

The proposal that the classical approximation is adequate for brain dynamics needs to be justified by calculations based on the more accurate quantum theory. Such calculations have been carried out, and they show just the opposite: they show, as discussed earlier, that quantum effects inside nerve terminals *can have* important macroscopic dynamical consequences. Hence quantum theory certainly needs to be used for a fully coherent treatment of brain processes, and the only currently available form of quantum theory that is technically adequate for this purpose, namely von Neumann’s version, injects the mind, irreducibly, into the dynamical workings of the brain.

The key practical question is then: Does it make any difference in evolving scientific practice whether or not we use the apparently necessary existence of von Neumann’s Process I. or can we simply ignore it?

A first question is: What is current scientific practice, and how is it evolving?

To get a perspective on this question I shall quote from an article that just appeared on a respected electronic forum dealing with the mind-brain problem. The forum is called Psyche-D, and the article is authored by Eddy A. Nahmias of the Department of Philosophy at Florida State University. The paper is entitled “Verbal Reports of the Contents of Consciousness: Reconsidering introspective psychology.”
[http://psyche.cs.monash.edu.au/v8/psyche-8-21-nahmias.html]

This paper is pertinent because it sketches out, from a philosophical standpoint, the development of psychology from “introspectionism,” to “behaviorism,” to contemporary “cognitive psychology.” The author notes that whereas introspectionism went to the extreme of banning the brain from psychology, and behaviorism went to the opposite extreme of banning consciousness, cognitive psychology, though strongly biased by its behaviorist roots, does use verbal reports, and sometimes treats these reports not as mere behavioristic responses, but rather as indicators of properties of existing experiential states. The author suggests that the time is now ripe for a limited rehabilitation, with appropriate care, of some of the methods and goals of introspectionist psychology, though not their views on the nature of mind. He notes that cognitive scientist interested in consciousness “avoid flirting with dualism” and recognize that “denying dualism need not mean denying a role for introspection.” He says that “To approach these questions we should first avoid several potential roadblocks. First, we should not assume that the methodology of introspectionism cannot be separated from its problematic philosophy, such as its inherent dualism … . “

These words draw attention to a certain incongruity in that approach to the study of the mind-brain problem: while the rhetoric hews closely to the behavioristic philosophy of rejecting that “bete noire”, *duality*, actual practice deals with two kinds of data, those arising from physical measurements of brain process and those arising from verbal reports that are treated as indicators of states of consciousness. Given this duality displayed in both contemporary empirical practice and in the immediate direct theoretical interpretation of verbal reports, what is the rational basis for persisting in the philosophical rejection of duality?

Daniel Dennett put his finger on the reason. His book “Consciousness Explained” has a chapter “Why Dualism Is Forlorn”, which begins with the words:

“The idea of mind as distinct …from the brain, composed not of ordinary matter but of some other special kind of stuff is dualism, and it is deservedly in disrepute today. … The prevailing wisdom, variously expressed and argued for is materialism: there is one sort of stuff, namely matter---the physical stuff of physics, chemistry, and physiology---and the mind is somehow nothing but a physical phenomenon. In short, the mind is the brain.”

Dennett then asks: “What, then, is so wrong with dualism? Why is it in such disfavor?”

He answers:

“A fundamental principle of physics is that any change in the trajectory of a particle is an acceleration requiring the expenditure of energy …this principle of conservation of energy … is apparently violated by dualism. This confrontation between standard physics and dualism has been endless discussed since Descartes’s own day, and is widely regarded as the inescapable flaw in dualism.”

This argument depends on identifying “standard physics” with nineteenth century physics. But the argument collapses when one goes over to contemporary physics, in which, due the Heisenberg Uncertainty Principle, trajectories of particles are replaced by cloud-like structures, and in which, moreover, consciousness can influence brain activity without violating the laws of physics. Contemporary physical theory allows, and in its von Neumann form entails, an interactive dualism. So there is no good reason to dismiss or rule out the possibility that a useful scientific concept of a human person could be built on the idea that mind and brain are two aspects of personhood that are most adequately described in psychological and physical terms, respectively, and that they interact in the way described by contemporary physical theory, namely von Neumann quantum theory.

It may be useful to elaborate on this point within the framework of Nahmias’s sketch of the development of psychology during the twentieth century.

In 1898 the introspectionist E.B. Titchener delineated the proper study of psychology as the conscious mind, defined as “ nothing more than the whole sum of mental processes experienced in a single lifetime.” And: “We must always remember that, within the sphere of psychology, introspection is the final and only court of appeal, that psychological evidence cannot be other than introspective evidence. ”

However, the psychologist William James (1892), who used introspection extensively, but recognized a causal link of consciousness to brain process, lamented that psychology had not developed any laws: “ We do not even know the terms between which the elementary laws would obtain if we had them.”

J.B. Watson, emphasing the failures of introspection to achieve reliable results, went to the opposite extreme. He began his 1913 behaviorist manifesto with the words: “Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness.”

The behaviorist movement made rapid gains and in 1917 H. W. Chase wrote a summary of the years work on “Consciouseness and the Unconscious” in which he reports:

“There can be no question that consciousness is rapidly loosing its standing as a respectable member of the psychologist’s vocabulary. Titchener in the preface of his new book says: I have avoided the use of the word ‘consciousness.’ Experimental psychology has made a serious effort to give it scientific meaning, but the attempt has failed, the word is too slippery, and so is better discarded.”

However, behaviorism began to have increasing technical difficulties with verbal reports of conscious experiences. Nahmias stresses that when we use a thermometer to measure the temperature of some system, what is important is not the point to which the Mercury rises: what is important is the property of the system that the position of the indicator reliably reports. Likewise, in verbal reports of conscious experience it is not the sounds themselves that are important: it is the property of the human system that the sounds reliably report.

The technical difficulties with behaviorism continued to mount, but, in Nahmias’s words, “It was not until Chomsky’s (1959) famous review of Skinner’s … analysis that the tide fully turned against trying to treat language, including reports about human experience, just like any other behavior.” But this turning of the tide meant that behaviorism failed precisely as the point at issue: the connection of physical process to conscious process. Yet the pariah status that behaviorism had assigned to dualism continued to persist after the fall of behaviorism, and it still persists today, as the words of Dennett show, and the commentary of Nahmias confirms.

Nahmias goes on to laud cognitive science, with its more inclusive approach of trying to correlate measured brain activity with reports of consciousness. He argues that these reports, at least in some cases, seem to be reports *about something*: they are not just sounds to be interpreted merely as sounds. "They are interpreted as reliable indicators of experiences." And he goes on to suggest that maybe some of the ideas of the introspectionists can, under special conditions, be useful in developing an idea of a structure of consciousness that could be correlated with the structure of brain activity.

This rehabilitation of consciousness is both reasonable and useful. And it is in line with the twentieth century developments in physics. But the concept of a "correlation" between consciousness and brain activity is significantly different from, and weaker than, the concept of an "interaction" between two individually incomplete components of reality, which is the picture that quantum theory gives.

The brain plays a vital role in quantum brain dynamics. So the inclusion of Process I in the dynamics is not meant to be, and is not, an opening to mysticism. It is an acceptance of a conclusion that arose *within science*, namely the fact that quantum theory---in its von Neumann form---entails that our streams of consciousness are potent contributors to brain dynamics. Since our streams of consciousness are also the basis of all science, it is hardly anti-scientific or mystical to include them in a scientific account of nature.

The existence Process I entails an incompleteness of the local deterministic Process II. This means that within von Neumann quantum theory the classical idea that brain dynamics is controlled basically by a local mechanical process is false, and that any attempt to force our understanding of brain process to fit that mold must fail.

Process I involves non-local operators P, which specify the brain correlates of psychological realities. This suggests that an adequate theory of the activity of a thinking brain ought to be a psycho-physical theory that includes, irreducibly, both psychologically and physically described realities.

One would think that this plausible view would reign today as the orthodox and main stream program, instead of being a fiercely opposed anathema that in Dennett's words "is deservedly in disrepute today."

Once it is appreciated that the local mechanical classical laws *must fail*, and that the quantum Process I injects into brain dynamics the efficacious consequences of *conscious thoughts*, it becomes reasonable to believe that a scientifically acceptable theory of brain activity could be described fundamentally in psycho-physical terms rather than in local mechanistic terms alone. There is no scientific basis for going either to the extreme of building the basic theory of the mind-brain on brain alone, as the materialist or physicalists demand, or to the extreme of building the theory on mind alone, as the idealists and humanists would have it. Quantum theory provides the basis for a dynamically coherent middle way that includes both the mental and physical aspects of reality without replacing either one by the other.

## 13. VALUES.

This book began with the observation that what science says about what you are, and how you are connected to the rest of nature, can affect your values, and hence your life. It also affects the ideas of influential thinkers, and consequently the social milieu that undergirds your thinking.

Our focus so far has been upon the twentieth-century revolution in what science says about these matters. That century began with science proclaiming the simple doctrine of a fully mechanical universe; of a universe consisting of tiny realities whose lawfully specified interactions with immediate neighbors fix the entire course of history from primordial initial conditions. Thoughts, ideas, and feelings need never be considered, because the dynamical rules can be stated---and their consequences fully determined---without ever acknowledging the existence of such entities. But that old mechanical picture, however simple and attractive it was, cannot describe the dynamics of human brains. In that system, for reasons spelled out earlier, quantum effects are important, and the only physical theory that seems adequate to deal with a thinking brain is the formulation of quantum theory devised by John von Neumann. This theory, like its classical predecessor, has a causal process that is fully determined by the interactions between tiny neighboring entities. Von Neumann calls this process by the name Process II. However, this mechanism by itself it does not yield a complete scientific theory: it is augmented by another process, called Process I, which injects effects of our feelings directly into workings of the brain. The older classical mechanical laws are seen to be an approximation to the quantum laws that systematically excludes all quantum effects, and hence, in particular, the dynamical effects of mind upon brain. The classical laws are therefore blinkered: they systematically cut from view the effects of a mind upon the brain connected to it.

Having explained these critical developments in science we can turn now to the question of their impact upon human values.

I have already mentioned the question of personal responsibility for one's acts. This concept has been greatly corroded by the classical notion that we are simply the product of our genes and our environment, and hence cannot be responsible for anything we do: that our actions are just automatic consequences of blind local mechanical processes. The notion that a person's mental effort can, to a large degree, control his actions is thus dismissed as an illusion, disproved by "modern science," which purportedly reveals us to be mechanical automata deluded by the absurd belief that such insubstantial and immaterial phantasms as our thoughts could affect the implacable march of the atoms.

There can be no doubt that this notion of the ineffectualness of our minds to control our actions has gained great standing and credibility in our legal, social, intellectual, institutional, and philosophical systems, and that this idea has drawn immense support from the authority of science. But the picture of the human agent that emerges from orthodox quantum theory is far more intricate, and not at all in line with the classical idea of a mechanical automaton. The new conception of Man entails the effectiveness of the action of mind on brain. The new physics describes, in particular, a specific mechanism whereby mental effort can in principle hold at bay the strongest forces arising from the mechanical side of nature. This development in physics belies the claim of human incapacity asserted by nineteenth century science, and rescues both the deliverances intuition about human nature and with it the notion that a human being is responsible for what he does.

This re-assessment of the freedom and efficacy of human volition gives you an image of yourself that is profoundly different from the idea that flows from classical physics. The latter portrays you as basically as a pile of dirt, or a vehicle constructed by mindless genes for a purpose they do not know. Those pictures contrast starkly to the quantum image of you as a center of power and creativity that gives form to your part of the universe.

This brings us to the basic issue of self image. What are you? How do you fit in to the reality that supports your being? How do go about forming opinions on these matters? Do you buy the pronouncements of some "authority," such as a church, a state, or a social or political group? All of these entities have agendas of their own. Where can you find unbiased truths?

Science rest, in the end, on an authority that is beyond the pettiness of human ambition. It rests, finally, on stubborn facts. Physicists certainly did not want to bring down to the grand structure of classical physics of which they were the inheritors, beneficiaries, and torch bearers. The stubborn facts forced their hand, and made them do what logic had demanded from the start: create an understanding of nature that encompasses human thoughts. The labor of scientists endeavoring to understand our non-human environment produced a rationally coherent framework for a better understanding of the causally efficacious place of the human person within that enveloping reality.

## 14. RECAPITUALIZATION AND RAMIFICATIONS.

You may have found it difficult to believe yourself to be what classical physics claimed you to be, namely a blob of protoplasm constructed by protein molecules as a consequence of some freakish quirks in the laws of nature, and lodged in an essentially mindless universe where thoughts can do nothing that mindless particles have not already done. That morally corrosive picture you, and of every one of us, is even today being drummed incessantly into the heads of us all, including our impressionable children as the lofty word of science, in spite of its having been found, many decades ago, to be incompatible with scientifically established facts.

This pervasive indoctrination is certainly not devoid of effect. The behavior that this dreary, debasing, and inconsistent self-image promotes is unquestionably far different from the behavior naturally generated by the rationally coherent and empowering quantum image of man.

You might now say: So what's new? I always knew my thoughts influenced my actions!

You may indeed have always known this. Your knowledge that your mental efforts can affect your bodily behavior is something you learned in the first few months after birth, and is fundamental to your dealings with the world. However, the conflict between that seemingly obvious truth and Newtonian physics produced three hundred years of philosophical turmoil that spilled over into the political, social, legal, educational, and moral arenas, and deeply affected the intellectual climate in which you are imbedded, and thereby your conception of yourself as part of the universe.

Philosophers tried doggedly for three centuries to understand the role of mind in the workings of a brain conceived to function according to principles of classical physics. We now know no such brain actually exists: no brain, body, or anything else in the real world is composed of those tiny bits of matter that Newton imagined the universe to be made of. Hence it is hardly surprising that those philosophical endeavors were beset by enormous difficulties, which led to such positions as that of the `eliminative materialists', who hold that our conscious thoughts do not exist; or of the `epiphenomenalists', who admit that human experiences do exist but claim that they play absolutely no role in how we behave; or of the `identity theorists', who claim that each conscious feeling is exactly the same thing as a motion of the particles that nineteenth century science thought brains and everything else in the universe to be made of, but that we now know do not exist, at least as they were formerly conceived. The tremendous difficulty in reconciling causally efficacious thought with the older physics is dramatized by the fact that for many years the mere mention of "consciousness" was considered evidence of backwardness and bad taste in most of academia, including, incredibly, even the philosophy of mind.

What you are and, will be, depends largely upon your values. Values arise from self-image: from what you believe yourself to be. Generally one is led by training, teaching, propaganda, or other forms of indoctrination, to expand one’s conception of the self: one is encouraged to perceive oneself as an integral part of some social unit such as family, ethnic or religious group, or nation, and to enlarge one’s self-interest to include the interests of this unit. If this training is successful your enlarged conception of yourself as good parent, or good son or daughter, or good Christian, Muslim, or Jew, causes you to give weight to the welfare of the unit as you would yourself. In fact, if well conditioned you may give more weight to the interests of the group than to the well-being of your bodily self.

In the present context it is not relevant whether this human tendency to enlarge one’s self image is a consequence of natural malleability, instinctual tendency, spiritual insight, or something else. What is important is that we human beings do in fact have the capacity to expand our image of "self", and that this enlarged concept can become the basis of a drive so powerful that it becomes the dominant determinant of human conduct, overwhelming every other factor, including even the instinct for bodily survival.

But where reason is honored, belief must be reconciled with empirical evidence. If you seek evidence for your beliefs about what you are, and how you fit into nature, then science claims jurisdiction, or at least relevance. Physics presents itself as the basic science, and it is to physics that you are told to turn. Thus a radical shift in the physics-based conception of man from that of an isolated mechanical automaton to that of an integral participant in a non-local holistic process that gives form to the evolving universe is a seismic event of potentially momentous proportions.

The quantum concept of man, being based on objective science equally available to all, rather than arising from special personal circumstances, has the potential of providing a universal system of values suitable to all people, without regard to the accidents of their origins. With the diffusion of this Quantum Conception of Human Beings, science may fulfill itself by adding to the material benefits it has already provided a philosophical insight of perhaps even greater ultimate value.

This issue of the connection of science to values can be put into perspective by seeing it in the context of a thumb-nail sketch of history that stresses the role of science. For this purpose let human intellectual history be divided into five periods: traditional, modern, transitional, post modern, and contemporary.

During the “traditional” era our understanding of ourselves and our relationship to nature was based on “ancient traditions” handed down from generation to generation: “Traditions” were the chief source of wisdom about our connection to nature. The “modern” era began in the seventeenth century with the rise of what is still called “modern science”. That approach was based on the ideas of Bacon, Descartes, Galileo and Newton, and it provided a new source of knowledge that came to be regarded by many thinkers as more reliable than tradition.

The basic idea of modern science was “materialism”: the idea that the physical world is composed basically of tiny bits of matter whose contact interactions with adjacent bits completely control everything that is now happening, and that ever will happen. According to these laws, as they existed in the early twentieth century, a person’s conscious thoughts and efforts can make no difference at all to what his body/brain does: whatever you do was deemed to be completely fixed by local interactions between tiny mechanical elements, with your thoughts, ideas, feelings, and efforts, to the extent that they entered at all, being simply locally determined high-level consequences of the low-level mechanical process, and hence basically just elements of a reorganized way of describing the effects of the microscopic causes.

This materialist conception of reality began to crumble at the beginning of the twentieth century with Max Planck’s discovery of the quantum of action. Planck announced to his son that he had, on that day, made a discovery as important as Newton’s.

That assessment was certainly correct: the ramifications of Planck’s discovery were eventually to cause Newton’s materialist conception of physical reality to come crashing down.  Planck’s discovery marks the beginning of the “transitional” period.

A second important transitional development soon followed:

In 1905 Einstein announced his Special Theory of Relativity. It denied the validity of our intuitive idea of the instant of time “now”, and promulgated the thesis that even the most basic quantities of physics, such as the length of a steel rod, and the temporal order of two events, had no objective “true values”, but were well defined only “relative” to some observer’s point of view.

Planck’s discovery led by the mid twenties to a complete breakdown, at the fundamental level, of the material conception of nature. A new basic physical theory was developed, principally by Werner Heisenberg, Niels Bohr, Wolfgang Pauli, and Max Born, and it brought “the observer” explicitly into physics. The earlier idea that the physical world is composed in part of tiny particles was abandoned in favor of a theory of natural phenomena in which the consciousness of the human observer is ascribed an essential role. This successor to classical physical theory is called “Copenhagen quantum theory”.

This turning away by science itself from the tenets of the objective materialist philosophy lent support to Post-Modernism. That view, which emerged during the second half of the twentieth century, promulgated, in essence, the idea that all “truths” were relative to one’s point of view, and were mere artifacts of some particular social group’s struggle for power over competing groups. Thus each social movement was entitled to its own “truth”, which was viewed simply as a socially created pawn in the power game.

The connection of Post-Modern thought to science is that both Copenhagen Quantum Theory and Relativity Theory had retreated from the idea of observer-independent objective truth: science in the first quarter of the twentieth century had not only eliminated materialism as a possible foundation for objective truth, but had discredited the very idea of objective truth in science. Yet if the community of scientists have renounced the idea of objective truth in favor of the pragmatic idea that “what is true for us is what works for us,” then every group becomes licensed to do the same, and the hope evaporates that science might provide objective criteria for resolving contentious social issues.

This philosophical shift has had profound social ramifications. But the physicists who initiated this mischief were generally too interested in practical developments in their own field to get involved in these philosophical issues. Thus they failed to broadcast an important fact: already by mid-century, a development in physics had occurred that provides an effective antidote to both the 'materialism' of the modern era, and the 'relativism' and 'social constructionism' of the post-modern period. In particular, John von Neumann developed, during the early thirties, a form of quantum theory that brought the physical and mental aspects of nature together as two aspects of a rationally coherent whole. This theory was elevated, during the forties---by the work of Tomonaga and Schwinger---to a form compatible with the physical requirements of the Theory of Relativity.

Von Neumann's theory, unlike the transitional ones, succeeded in integrating into one coherent idea of reality the empirical data residing in subjective experience with the basic mathematical structure of theoretical physics. Von Neumann's formulation of quantum theory is the starting point of all efforts by physicists to go beyond the pragmatically magnificent but ontologically incomplete Copenhagen form of quantum theory.

Von Neumann capitalized upon the key Copenhagen move of bringing human knowings into the theory of physical reality. But, whereas the Copenhagen approach excluded the bodies and brains of the human observers from the physical world that they sought to describe, and renounced the aim of describing reality itself, von Neumann demanded logical cohesion and mathematical precision, and was willing to follow where this rational approach led. Being a mathematician, fortified by the rigor and precision of his thought, he seemed less intimidated than his physicist brethren by the sharp contrast between the nature of the world called for by the new mathematics and nature of the world that the genius of Isaac Newton had concocted.

The common core feature of the orthodox (Copenhagen and von Neumann) quantum theory is the incorporation of human knowings and actions into the structure of basic physical theory. How this is done, and how the conception of the human person is thereby deeply altered, is something every well informed person ought to know about.

It is curious that some physicists want to improve upon orthodox quantum theory by excluding “the observer”, who, by virtue of his subjective nature, must, in their opinion, be excluded from science. That stance is maintained in direct opposition to what would seem to be the most profound advance in physics in three hundred years, namely the overcoming of the most glaring failure of classical physics, its inability to accommodate us, its creators. The most salient feature of quantum theory is that the mathematics has a dynamical gap that, by virtue of its intrinsic form, provides a perfect place for Homo sapiens as we know and experience ourselves. That was the conclusion recognized by the founders of quantum theory already in 1926, and clarified by von Neumann in 1932.

In view of the severe philosophical difficulties that arise from the classical conception of the detached mind it is odd that anyone would want to revert to it.